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THE COLOR OF WATER.

BY DESMOND FITZGERALD AND WILLIAM E. FOSS.

As many cities and towns are obliged to depend upon surface waters for their supplies, and as surface waters are liable to be discolored by the vegetable matter with which they come in contact, making them objectionable in appearance, it is important to have an accurate scale with which to measure the amount of the discoloration.

For several years past, this matter has received much attention upon the Boston Water Works. One of the principal sources supplying the city of Boston is that of the Sudbury River. The area of the water-shed above the point of taking, is about seventy-four square miles. On this area several large storage reservoirs have been built for the purpose of equalizing the yield of the streams. As the sites of the reservoirs have been mostly stripped of all organic matter, the effect of storage is to reduce the color of the water delivered by the feeders, but as it is impracticable to keep

the water in store long enough to decolorize it completely, much study has been given to the source and amount of the color delivered by the streams supplying the reservoirs. It has been found, as was expected, that the swamps and meadows were the principal sources of color.

In July, the color of the water coming from the swamps is a rich reddish-brown, and in the autumn, after the leaves have fallen, the color has more of a greenish cast.

The color of the brooks varies constantly during the year, depending largely upon conditions which cannot be now discussed. In winter the color is naturally low. In the spring the color is high, reaching its maximum in June, and a second maximum occurs in December.

In making plans for the improvement and drainage of the swamps it became important to be sure of the measurement of the colors, and as the color of the Boston water is almost an exact gauge of the organic matter which it contains, it also became important that the color of the water delivered to the consumers should be readily and accurately measured on some correct scale. It is the purpose of the writers of this article to consider here the matter of scale and methods of comparison.

When solar light is transmitted through a water containing foreign matter, some of its components are wholly or partially absorbed and the transmitted light is more or less colored in consequence. The color depends on the nature of the missing rays, or is the resultant of the rays which have been transmitted. The greater the depth of the water through which the light is transmitted, the greater will be the effect on the component and the more marked the color. Light which has traversed a depth of two meters of distilled water has only a very slight blue color, hence it can be said that in pure water all of the component colors are transmitted with almost equal facility.

The color standards at first used on the Boston Water Works were prepared by diluting portions of a highly colored water with distilled water until the colors matched those produced by nesslerizing varying amounts of an ammonia solution (0·01 Mg NH_3 per cc.) in fifty cubic centi-

meters of distilled water; the color being recorded as the number of cubic centimeters of the ammonia solution used.

These water standards are, therefore, as near as possible duplicates of the nesslerized ammonia standards employed for reading the color of water. They are much more convenient to use, because their color does not change as rapidly as that of the nesslerized ammonia solutions, which have to be mixed fresh at every observation. A set of standards having been prepared in the above manner, the color of a water is determined by comparison in Nessler tubes, which are of glass, about 15 to 20 millimeters in diameter and 300 millimeters in length and closed at one end. The tubes are filled with the different standards to a depth of 200 millimeters. A similar tube filled to the same depth with the water to be examined is moved along the scale until a point is reached where its color matches one of the standards. All of the tubes are viewed against a white background. When the color of the water falls between two consecutive standards, the color is estimated by the observer.

These natural water standards, although an improvement over the nesslerized ammonia standards, were found to be very unsatisfactory, for the following reasons:

They did not remain constant in color, but were found to change even when kept in the dark.

Standardizing a set against the nesslerized ammonia was very difficult, because the conditions when preparing a set of nesslerized ammonia solutions had to be always exactly similar in order to obtain uniform results.

It was also found that owing to irregularities in the scale the color of a water when diluted with distilled water would not vary with the dilution.

It was found that the platinum standard recently suggested by Dr. Allen Hazen* was not open to these objections, and was a much better standard to use.

"On the platinum standard the color of a water is the amount of platinum, in parts per ten thousand, which in

* *Amer. Chem. Journal*, Vol. XIV, No. 4.

acid solution, with so much cobalt as will match the hue, produces an equal color in distilled water."

In preparing a set of standards, a standard solution having a color of 5·00 is usually prepared, and from this the lower standards are prepared by dilution with distilled water.

On this standard then, from the method of its preparation, the color of a water when diluted with distilled water will vary directly with the dilution.

The platinum standard which has been found to match the Boston water best, contains twenty-five parts of cobalt to fifty parts of platinum. It has been found to keep for months without change if protected from dust.

The method of comparing colors in Nessler tubes was not considered satisfactory. The color of a water falling between two consecutive standards depended largely upon the judgment of the observer. It was believed that a more convenient method could be obtained, and the colorimeter, shown on *Plate 1*, was designed to overcome these objections. *Plate 1* shows an isometric projection of the complete instrument and a section of the eye-piece. The latter consists of two totally reflecting prisms *A* and *B*, and a magnifying lens *C*. The lens is free to slide in the brass tube *D*, so that it can be focussed on the upper face of the prisms. The field of view is cut down to a circle by a diaphragm *E*, at the lower end of the tube *D*.

Rays of solar light from some uniform source, after passing through the water placed in tube *F*, which has a plate-glass end, enter the prism *A*, and emerging, illuminate one-half of the circular field of view.

Rays of light from the same source after passing through the standard solution in tube *G*, enter prism *B*, and are totally reflected at its surface, and emerging illuminate the other half of the field of view. The colors produced by the absorption of the two liquids can then be readily compared and brought to the same value, as follows:

The standard solution is held in a glass jar, and is connected by means of a glass tube with the standard tube.

The top of the jar is furnished with a piece of flexible

rubber tubing, terminating in an inflating bulb. By means of the latter the observer increases the depth of the standard solution in the standard tube, until the color produced on the field of view matches that of the water in the other tube; he then closes the pinch-cock on the tubing and reads the color of the water from the scale on the standard tube.

The color of a water determined by comparison in the colorimeter, should differ slightly from the color obtained by comparison in Nessler tubes and using the platinum standard, due to the fact previously mentioned that distilled water has a slight blue color. In the colorimeter the portion of the tube above the standard is not filled with distilled water, while in the Nessler tubes it is filled.

The following readings of a set of platinum standards in the colorimeter having some 1.00 platinum standard in the jar, are the average of two sets of readings by independent observers. They show that the maximum error does not exceed 0.02.

In cases where greater accuracy is required for water having a low color, a 0.50 standard should be substituted for the 1.00 in the jar.

Platinum Standard.	*Colorimeter Reading*
0.10	0.115
0 20	0.22
0.30	0.32
0.40	0.40
0.50	0.50
0.60	0.595
0.70	0.70
0.80	0.80
0.90	0.895
1.00	1.00

The rapidity with which comparisons could be made by means of the colorimeter led to quite extended observation to determine the irregularities of the nesslerized ammonia and natural water scale already mentioned. On the lower portion of *Plate 2* these irregularities are illustrated graphically. The upper scale represents a uniform gradation, and the middle one the gradation corresponding to the nesslerzed ammonia and natural water scales, and represents the

scale as determined by the average of observations made by two independent observers upon a set of natural water standards which had just been standardized against the Nessler solutions. The determinations were made with the colorimeter having some 1·00 natural water standard in the jar.

The lower scale shows the irregularities of the natural water and nesslerized ammonia scales as determined from the average of observations on fifteen sets of natural water standards made by three independent observers.

The differences between the two scales are probably due to the difficulty previously mentioned in preparing the nesslerized ammonia solutions and also to changes having taken place in the natural water standards after being standardized.

That the irregularities in the nesslerized ammonia and natural water scales are due to the method of preparation and not to any error introduced by the colorimeter, was shown by preparing a set of colors by diluting a 1·00 natural water standard with distilled water, and then reading these colors on the colorimeter, having some of the original 1·00 natural water standard in the jar. The following are the results:

Dilutions of 1·00 Standard.	*Reading on Colorimeter.*
·10	·095
·20	·21
·30	·295
·40	·405
·50	·52
·60	·60
·80	·80
1·00	1·00

From these investigations it was learned that the nesslerized ammonia and natural water standards were of very little value for accurate color readings.

To illustrate the misleading results obtained by using these standards, the following example may be taken:

Water having a color of 0·40 on the Nessler scale before filtration was found to have a color of 0·10 after filtration, showing a reduction of seventy-five per cent. by the process of filtration. By the uniform scale, however, shown

on *Plate 2*, this reduction is really only about fifty per cent.

Before the present form of the colorimeter was finally adopted, two methods were suggested by which the colors produced by the absorption of light by the standard solution and those produced by the water alone could be made to match.

The first was to vary the depth of the water under examination, while the depth of the standard remained constant. The second was to vary the depth of the standard, while the depth of the water remained constant.

A study of the first method showed that the depth of water could be varied between certain limits, only and that it was better, for accurate results, to keep the water under examination of a fixed depth. As the bottom of the tube is approached, the change in color, corresponding to any given decrease in depth of water, increases rapidly. It was decided that 200 millimeters would be the most convenient length for the tube, and that the scale divisions should not be less than two millimeters to be read accurately: also that a difference in reading of one scale division should not make an error in the resulting color of more than four per cent. It was also assumed for purposes of calculation that the color of the water and standard varied directly with the depth; that is, if the color of a water in a depth of 100 millimeters equals that of the standard in depth of 200 millimeters, then the color of the water would be twice that of the standard. If the color of the water in depth of twenty millimeters equals that of the standard in depth of 200 millimeters, then the color of the water would be ten times that of the standard.

The following table shows the increase of color corresponding to equal variation in depth of the water when a standard of 0·50 is used. It can be seen from the last column of this table how rapidly the differences of color, due to a decrease in depth of ten scale divisions, increases in the lower portion of the tube. It is thus evident that the readings of color in the upper portion of the tube

will be of much greater accuracy than those in the lower portion:

Standard.	Depth of Standard. M. M.	Depth of Water. M. M.	Calculated Color of Water.	Difference of Color for 10 Scale Divisions.
0·50	200	200	0·50	—
"	"	180	0·55	·05
"	"	160	0·62	·07
"	"	140	0·71	·09
"	"	120	0·83	·12
"	"	100	1·00	·17
"	"	80	1·25	·25
"	"	60	1·67	·42
"	"	40	2·50	·83
"	"	20	5·00	2·50

In the upper diagram, Plate 2, the colors obtained by calculation have been plotted for several different standards; the abscissas represent the depth of water in the tube and the ordinates the calculated color when using the standard marked on each curve.

The cross on each of the curves shows the point at which the error in a color reading, resulting from an error of one scale division in reading, would equal 4 per cent, For all waters having colors darker than this, a new standard must be employed.

In this way it was found that where waters having colors ranging from 0· to 1·00 are common, at least three standards are necessary. For quick, practical work this method would be very inconvenient.

The second method, however, was found to have none of these objections; it gave readings of equal value in all parts of the tube, and readings from 0· to 1·00 could be obtained with a single standard, as shown by following table:

Standard.	Depth of Water. M. M.	Depth of Standard. M. M.	Calculated Color of Water.	Difference of Color for 10 Scale Divisions.
1·00	200	200	1·00	·10
"	"	180	·90	·10
"	"	160	·80	·10
"	"	140	·70	·10
"	"	120	·60	·10
"	"	100	·50	·10
"	"	80	·40	·10
"	"	60	·30	·10
"	"	40	·20	·10
"	"	20	·10	·10
—	—	0	0	—

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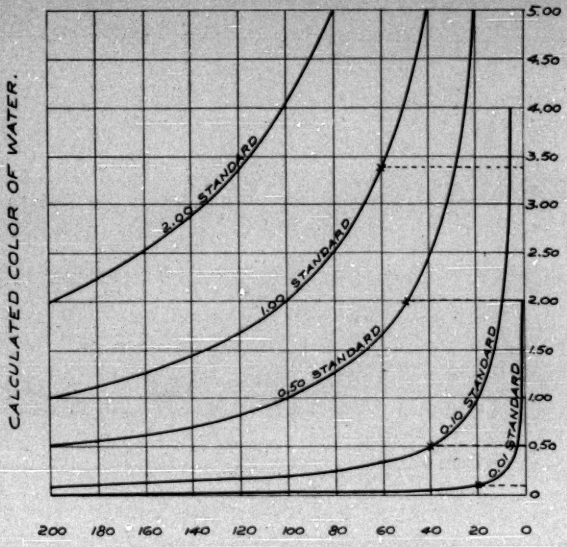
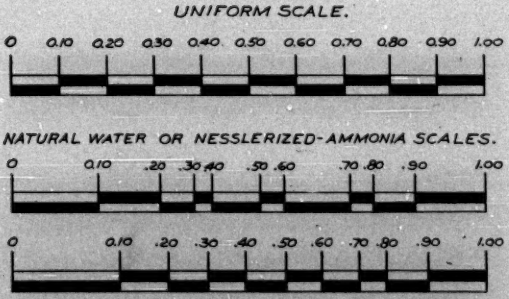

CALCULATED COLOR OF WATER.
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0
2.00 STANDARD
1.00 STANDARD
0.50 STANDARD
0.10 STANDARD
0.01 STANDARD
200 180 160 140 120 100 80 60 40 20 0
DEPTH OF WATER IN MILLIMETERS.

PLATE 2.


UNIFORM SCALE.
0 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
NATURAL WATER OR NESSLERIZED-AMMONIA SCALES.
0 0.10 .20 .30 .40 .50 .60 .70 .80 .90 1.00
0 0.10 .20 .30 .40 .50 .60 .70 .80 .90 1.00

LUMINOSITY.
INCIDENT LIGHT
WATER 100 M.M. DEEP
WATER 300 M.M. DEEP
STANDARD
a
b
c
A
B
C
D
E
F
G
H
RED
ORANGE
YELLOW
GREEN
BLUE
VIOLET
7500.
7000.
6500.
6000.
5500.
5000.
4500.
4000.
HUE OR WAVE LENGTHS IN 1/10 METERS.
LUMINOSITY.

PLATE 3.

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The platinum standard has been adopted for use on the Boston Water Works.

For converting any former readings on the Nessler or natural water scale to the platinum, the following table can be used. It was prepared from observations on fifteen sets of natural water standards.

TABLE FOR CONVERTING COLORS ON THE NESSLERIZED AMMONIA AND NATURAL WATER SCALES, TO EQUIVALENT VALUES ON THE PLATINUM SCALE.

Natural Water Scale	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
Equivalent on Platinum Scale	.18	.26	.33	/39	.46	.52	.58	.63	70	.81

For standards darker than 1.00 no satisfactory comparisons have yet been made. For reading colors darker than 1.00 it has been found best either to read in shorter depths or else dilute with distilled water in order to bring the color within the range of the 1.00 standard. The latter method has been adopted on the Boston Water Works. The reason for this is that it is often difficult to compare the dark waters with the standard owing to a difference of hue. It has been found that the amount of light which passes through a number of equal layers of an absorbing solution, diminishes in geometrical progression as the number of layers increase in arithmetical progression. Thus if I denotes the intensity of the incident light, Ia will be the intensity after transmission through unit thickness, where a is a proper fraction, and depends upon the nature of the substance and the refrangibility of the light employed. For a given wave length, a will be different for different substances; and for a given substance, a will vary with the wave length. The quantity a is termed the coefficient of transmission.*

It is because of the fact that the coefficient of transmission for the different rays varies with different solutions that we sometimes find a water matches the standard very closely in hue in a short depth, but appears of quite a different hue in a greater depth. This can be represented by a diagram as follows. Let the ordinates of the curve *a b c*

* Thomas Preston, *The Modern Theory of Light.*

in diagram, *Plate 3* represent the intensities of the incident rays of light from the red to the violet, which fall upon a water, and the standard with which it is compared. Then assuming the following coefficients of transmission for a depth of 100 millimeters.

	Standard.	*Water.*
Red	·1	·9
Orange	·5	·8
Yellow	·6	·6
Green	·9	·5
Blue	·9	·1
Violet	·9	·1

The intensities of the different rays after traversing 100 millimeters would equal their original intensity multiplied by their respective coefficients.

The intensities after traversing a depth of 300 millimeters would equal the original intensity multiplied by the third power of their respective coefficients giving the following:

	Standard.	*Water.*
Red	·001	·729
Orange	·125	·512
Yellow	·216	·216
Green	·729	·125
Blue	·729	·001
Violet	·729	·001

Plotting these values, gives the curves in the diagram. The upper curve shows the intensity of the different colors in the incident light, and the four other curves show the intensities after having passed through 100 and 300 millimeters of the standard and water respectively. Comparing the intensities after passing 100 millimeters of the water with those of the standard for the same depth, it is noticed that they do not differ much in hue or luminosity. Comparing the intensities after passing 300 millimeters of standard and water, it is noticed that the hue of the water has approached the red, while that of the standard has approached the blue.

These hues would therefore be quite different, and could not be accurately compared. The relative luminosity has also changed, the standard having become somewhat brighter than the water.

Color readings made by different observers, have been found to agree to within .02. Occasionally differences of .05 or more are found. These differences are usually found in cases where the water from turbidity or other causes differs from the standard in hue. This renders the comparison difficult, and the result depends largely upon the judgment of the observer.

The accuracy at present attained in color readings is probably quite sufficient for practical purposes.

The principal difficulty in the way of greater accuracy in color readings is the difference in hue between the prepared standard and the water. Maxwell, Young and Helmholtz claim that all color perceptions are due to the simultaneous excitation of three sets of nerve ends in the eye, and that all colors can be produced by a combination of three colors, red, green and blue in the proper proportion.

It is possible that a colorimeter might be constructed on this principle by employing standard red, green and blue solutions, so arranged that they could be combined in all proportions. A solution would also probably have to be employed to give the effect of turbidity to the standard.

With a colorimeter of this kind much more time would be required to make the comparison.

Prof. Ogden N. Rood* has employed these three constants to define completely a color.

(1) Purity, or freedom from white light.

(2) Luminosity, or brightness.

(3) Hue, or wave length.

To measure the color produced by the absorption of a water it could be arranged so that the measurement of the first constant would not be necessary. The light after passing through the water, would consist of several components. It would be necessary to separate these by means of a prism or grating, and compare the spectrum thus obtained, with the spectrum of the original light. The measurements of the hues could then be accurately made, and the luminosity would remain as a photometric problem.

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* Text-Book of Color. By Ogden N. Rood. 1892.

It appears, therefore, that in order to obtain much greater accuracy in color readings than is at present possible, more time and expensive apparatus must be employed. It would tend to uniformity of results and facilitate comparisons if all color readings were made on the uniform depth herein described, all water darker than 1·00 being diluted, as set forth on page 409.

One of the purposes of the writers of this article is to urge all chemists, analysts and others interested in matters of water supply to adopt the methods herein described, unless some better method can be found.

THE PHOSPHATES OF THE WORLD.*

BY FRANCIS WYATT, PH.D.

[*Continued from p. 347.*]

The cost of producing one ton of rock in dry marketable condition, is at the present moment generally allowed by the river companies to be about $2.75 per ton, including fifty cents royalty to the State, and well-managed land companies with no royalty to pay, place their cost of production at from $2.75 to $3 delivered free alongside vessels in Charleston harbor.

Of the total annual output, about two-thirds of nearly all the land-rock, are consumed in the United States, principally in Charleston, Richmond, Baltimore, Philadelphia and New York; the river-rock, which constitutes the remaining third, is exported.

As a raw material of the first-class in the manufacture of soluble and available phosphates, South Carolina rock is everywhere held in the highest esteem. In Europe it is very popular, and, being of unvarying quality, has yielded results that cannot be surpassed by any other phosphate as an all-round staple, uniform and reliable article.

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*A Lecture delivered before the Franklin Institute, January 12, 1894.

No absolute opinion can be expressed as to the probable extent and capacity of the yet untouched or unexploited land deposits and it would be manifestly absurd to attach undue importance to any estimate that might be formed. At the same time, my own investigations prompt me to suggest that it may probably extend over some thirty square miles. If the yield of this area were to approximate the present average of 750 tons to the acre, the conclusion would be that South Carolina may still produce about 14,000,000 tons of land phosphate.

As the time rolls on the manufacturing requirements of the State will increase in large proportions, and I sincerely hope and believe that this source of consumption will eventually absorb all that can be produced, and leave nothing available for foreign markets.

PHOSPHATE ROCK (WASHED PRODUCT) MINED BY THE LAND AND RIVER MINING COMPANIES OF SOUTH CAROLINA, SINCE THE DISCOVERY OF THE DEPOSITS.

	Long Tons.
1867, year ending May 31st	6
1868, " "	12,262
1869, " "	31,958
1870, " "	65,241
1871, " "	74,188
1872, " "	58,760
1873, " "	79,203
1874, " "	109,340
1875, " "	122,790
1876, " "	132,478
1877, " "	163,000
1878, " "	210,322
1879, " "	199,365
1880, " "	190,763
1881, " "	266,734
1882, " "	332,077
1883, " "	378,380
1884, " "	431,779
1885, " "	395,403
1885, (June 1st to December 31st)	277,789
1886, (calendar year)	430,549
1887,	480,553
1888,	448,567
1889,	548,585
1890,	537,149
1891,	400,000
1892,	350,000

Passing now to those deposits so recently developed in Florida, it is only fair to remark that they were really discovered and located in various directions throughout the State many years ago. They, however, were never believed to be of sufficient importance either in quantity or quality to merit serious attention, and like many of our natural resources, remained long dormant and unthought of.

The first serious attempt to develop them in 1888 was marked by the outbreak of a perfect fever of speculation. At that time our total annual output of phosphate was about 500,000 tons, nearly all of which was raised in South Carolina, about 200,000 tons being exported and the balance used at home.

The difficulties between the Coosaw Company and the South Carolina State authorities, brought about by the action of Governor Tillman, had only just arisen, and as the temporary suspension of this company's gigantic operations threatened a considerable decrease in production, buyers became anxious to secure their needed supplies, and sellers advanced their prices.

To the initiated, this was an intelligible and natural situation, on the one hand there was the probable deficiency of 100,000 tons by the Coosaw Company; on the other, there were the customers of this company anxious to supply their needs and ready to abide by a rise in price rather than be left unsatisfied. A fictitious activity was thus imparted to the industry, of which few, if any, of those who rushed into the Florida fields took the trouble to ascertain the true inwardness. To these eager speculators the only prominent phases were the demand for phosphate and the vast quantities ready to be exploited in Florida, at an exceptionally low price, and of exceptionally high quality.

They ignored the all important fact that the present demand for consumption of the entire world for mineral phosphates does not attain more than 2,000,000 tons, including all kinds and qualities, and disregarded the circumstances that three-fourths of this quantity are being raised in other countries, from mines almost as productive as our own, and that South Carolina might eventually be equal to any calls we might make upon her.

Thus company succeeded company; exaggerated values were placed upon Florida lands; the possibilities of consumption and production were ridiculously overestimated; and in lieu of looking to our own agriculture for an outlet, and thus awakening the interest of American farmers, the general attention was turned to Europe as a more proper, because supposed unlimited, consumer.

The result of such a "boom" and of such ignorance has been widespread and deplorable. The foreign buyers who were at first so skeptical of the existence and value of Florida phosphates, became seriously concerned at their abundance, and their anxiety for future supplies changed to apprehension when they saw themselves menaced with a glutted market. They knew and understood the impossibility of finding an outlet in any of the ordinary channels of trade, for such a flood of material as that with which they became threatened, and they took advantage of their knowledge to break down the hitherto firm prices of phosphates. So thoroughly did they master the situation, that the hapless Florida miners are now entirely at their mercy, and are confronted by quotations which have closed most of the world's phosphate mines, and at which even South Carolina, despite her natural advantages, can no longer make both ends meet.

This state of affairs would be sufficiently discouraging, even if the "boom" had resulted in a serious increase in the consumption of American phosphates. We might have found in such an increase some consolation from the fact of displacing foreign products, either at home or abroad, though prices were thereby lowered and mining profits reduced. A careful and impartial study of figures however, shows that this meagre satisfaction is denied us, for no such enormous increase in our total production, consumption or exports, has in reality taken place.

In the year 1890, for example, the total sales of American phosphates from all sources amounted to about 600,000 tons, and our average prices were $7 per ton for that which contained sixy per cent, and $12 per ton for that containing seventy-five to eighty per cent. phosphate of lime, both free on board out-going vessels.

In the year 1892 we increased our sales by eighteen per cent., or in other words, we sold about 700,000 tons. This surplus of only 100,000 tons, had such an extraordinary effect upon the markets of the entire world, that its disposal entailed a fall in price to $4.50 and $6.50 per ton for the respective qualities mentioned.

This remarkable disturbance, caused by this slight excess (a large proportion of which was of exceptionally high grade and good quality) graphically illustrates the present want of flexibility in the fertilizer markets, and, in my opinion, not only argues badly for the immediate future but should be a significant warning to our producers not to further overstep the bounds of prudence.

Whether the disturbed equilibrium can be restored now that we are at war with all other phosphate producers of the world, and how and when phosphate mining can again become one of our really profitable undertakings, are serious problems, but it is certain that, in proportion to the world's demands, there are now too many in the business, and that we must look forward to the collapse of a large majority of the mining companies, before entertaining hope for any sensible relief. The operation of the law of supply and demand is always absolute and inflexible, and it must be appreciated before the future of Florida as a phosphate producer can be established on a commercial basis. Directly its applicability is fully realized, her miners will be satisfied to rank as large contributors to the world's necessities, and will always then command sufficiently remunerative prices to repay them for the expenditure of capital and labor.

The geological formation in which the very remarkable Florida phosphate deposits are found, I may broadly summarize as being divided between the Eocene, Miocene and Pliocene ages. It is chiefly composed of:

(1) Original pockets or cavities in the Vicksburgh limestone filled with hard and soft phosphate and debris.

(2) Mounds or beaches rolled up on elevated points, and chiefly consisting of huge bowlders and large and small fragments of phosphate rock.

(3) Drift or disintegrated rock commonly called "pebbles"

covering immense areas, chiefly in Polk and Hillsboro counties, and underlying portions of Peace River and its tributaries.

The work of exploitation by regular mining and hydraulic methods has been prosecuted on a large scale at various points, which, if taken in their entirety, would probably cover an area of some 275 miles long and nearly seven miles wide on the western side of the Peninsula.

In several of the mines, notably in those of Marion and Citrus counties, the beds of phosphate have extended in many cases uninterruptedly over several acres and have been worked in the form of quarries. These beds have shown themselves to be combinations of the "original pocket" and the "mound formation," and the superincumbent material or over burden is principally sand, of an average depth of eight or ten feet and without any admixture of phosphate. The phosphate rock itself is sometimes in the form of enormous bowlders lying either singly, or cemented together in groups with clay, and sometimes in the form of small fragments imbedded in a white plastic or friable mass resembling kaolin. This white material is, like the fragmentary rock, undoubtedly the result of a natural disintegration, caused by the rolling, attrition, or concussion of the hard bowlders. The thickness of the phosphatic stratum varies within a range of from five to fifty feet, and cannot therefore, be computed with any accuracy into an average; and the limits of the superficial area occupied by the combined "pockety" and "mound" formations are so sharply defined, that the readily exploitable deposits of bowlder rock phosphate frequently terminate very abruptly and give place to an unimportant drift of fragmentary material. This drift generally crops out at the surface through the sand, and may sometimes be followed for such long distances without leading to a pocket of bowlders of exploitable value, that I believe it quite safe to place the actual phosphate producing area at a maximum of no more than 3 per cent. of that commonly attributed to the phosphate belt.

When the exploitable pockets are of any considerable

depth, they yield large quantities of merchantable phosphate, but I have found that as a rule they are very superficial, and, in some of them, the underlying limestone is so near to the surface and the phosphate itself so mixed up with other and valueless material, that profitable extraction is impossible.

In the districts where no bowlders or other variety of hard-rock phosphate have been discovered, and where only "pebbles" abound, this capriciousness of the formation is much less marked, and, in fact, an unusual degree of regularity may be said to characterize the occurrence of what is commonly known as the "land pebble" phosphate throughout the extensive area in which it has been found. This area may be roughly said to take its point of departure in Polk County a little south of Bartow, and thence to practically continue with a gradually narrowing tendency to within a very short range of Charlotte harbor. The "pebble" country is flat, swampy, and extremely unhealthy. It is intersected at frequent intervals by the Alafia, Manatee, Peace and other rivers, rivulets and streams, and extensive exploratory work has demonstrated that it is largely underlaid with a nodular phosphate stratum of a thickness varying from a few inches to thirty feet, with an overburden of sand and clay that may be fairly averaged at about eight feet.

The most important working centre for "pebble" phosphate is Peace River, which rises in the high lake lands of Polk County, and flows rapidly southward into the Gulf of Mexico. Its course is extremely irregular, and its bottom is a constant succession of shallows and deep basins. Lakes Tsala, Opopka and Chillicohatchee, and Pains and Whidden Creeks are its chief tributaries, and I have satisfied myself by careful examination that they are the main sources of its phosphate deposits, since the phosphate "pebbles" are without doubt washed out from their banks and borne along their beds into the river by the torrential summer rains.

The phosphate "pebbles" when pumped out of the river and freed from impurities and dried, vary in size from a grain of rice to about one inch in diameter, and they are

intimately mixed up with the bones and teeth of numerous extinct species.

The only difference between them and the "land" pebbles, is that the latter are of a lighter color and are imbedded in a matrix of sand and clay, to which they frequently bear the proportion of about twenty per cent. by weight.

Although the origin of these Florida deposits has naturally been very much discussed, and a great number of more or less plausible theories has been advanced, I doubt whether any particular one has yet been sufficiently supported by evidence to warrant its general acceptance. I have personally devoted to it a great deal of observation and thought, and so far as I have gone I believe the most satisfactory explanation is that which ascribes them to a deposition resulting from previous solution. Apart from the probable existence of bird guano deposits in large quantities on their exposed surfaces, the Vicksburgh limestones all contain in themselves notable proportions of phosphate of lime, and the seas of that age were certainly charged with sufficient carbon dioxide to dissolve both carbonate and phosphate of lime in large quantities. Having entered into solution the phosphate, at a subsequent period, was re-deposited under conditions favorable to its separation. What these conditions most probably were I need not pause to discuss at any length, but I think it will be obvious that they might have been either a simple interchange of bases between the dissolved phosphate and the limestone bed, or a mere lowering of the solvent powers of the water by evaporation and loss of carbonic acid gas. In either case the final result would be the formation, principally in the neighborhood of the rock cavities produced by the leaching process, of large and small estuaries, and those estuaries being certainly replete up to a certain point, with life and vegetable matter, the continuous concentration of the waters ultimately induced complete precipitation and a multitude of readily conceivable subsequent processes of decomposition and metamorphism.

It may be very rationally surmised, for example, that among the chief of these processes and decompositions, when the "drying-up" was nearly complete, would be the

combination of the liberated phosphoric acid, and the ammonia, resulting from the breaking up of the albuminoids of the organic matter. The diammonium phosphate thus formed would be dissolved by subsequent waters, and, percolating through the overlying mass of the deposit, would saturate the calcareous marls as well as the soft and porous limestone underneath. A double decomposition would thus be induced, with formation of hydrogen calcium phosphate and ammonium carbonate: $2\ (NH_4)_2\ H(PO_4) + 2\ CaCO_3 = Ca_2\ H_2\ P_2O_8 + 2\ (NH_4)_2\ CO_3$.

In whatever manner it was originally formed, whether as a residium from leaching, a deposition from solution, or a product of decomposition and metamorphism, the phosphatized stratum was eventually cracked and broken up and was then hurled into yawning gaps and from one fissure to another. At the end of the tertiary period came the succeeding seas with their deposits of drifts and shells, sands, marls, clays and other transported material, and it is easy to assume that those portions of the phosphate crust which were not embedded in permanent limestone fissures or caverns during the Miocene age, subsequently became very thoroughly disseminated and disintegrated. The masses were rolled about and intermixed with sand, clay, and marls, and were banked up with them in various mounds or buried in depressions in conformity with the violence of the waters, or with the uneven structure of the surface to which they were transported.

Occasionally this drifting mass found its way into very deep hollows, in regions where considerable depressions were brought about by the sinking and settling of the substratum. At other times it was rolled to and deposited on slightly higher points. In the first of these cases we find a vast and complete agglomeration, comparable to an immense pocket, of broken-up phosphate rock, finely divided phosphate *débris*, sands, clays and marls, all heterogenously mixed in together. In the second case we find the phosphate in large bowlders, sometimes weighing several tons and intermixed with relatively, but, small proportions of any foreign substance.

THE CHEMICAL COMPOSITION OF FLORIDA PHOSPHATE

is as variable as its physical aspects, and I present the following averages of my own analyses for the purpose of general illustration:

	Bowlders washed, crushed, dried.	*Land Pebble.*	*River Pebble.*	*Soft White.*
Moisture	0·32	0·84	0·76	1·13
Organic and volatile	0·97	5·25	7·03	3·06
Phosphate of lime	82·80	70·50	60·84	72·23
Carbonate of lime	4·57	5·01	9·85	10·03
Carbonate of magnesia	0·46	0·32	0·87	0·74
Fluoride of lime	4·34	5·27	4·99	3·86
Oxides of iron and alumina,	2·20	2·96	3·57	4·01
Insoluble siliceous matter	4·20	9·00	12·03	4·54
Loss in analysis and undetermined	0·14	0·85	0·86	0·40
	100·00	100·00	100·00	100·00

It will be seen from these figures that, quite apart from its abundance, we are dealing with a product of the very first rank for the purposes of the fertilizer manufacturer. The unfortunate fact remains, however, that owing to certain established trade customs arising out of the long-continued use of South Carolina phosphate, there is no remunerative market in our own country at the present time for high-grade material, and this, consequently, has to be exported. Similarly established trade customs, arising out of similar causes, prohibit foreign buyers from accepting any phosphates containing a higher maximum than three per cent. of oxides of iron and alumina, and this compels our miners to guarantee an absolute limit to these impurities in all their shipments.

The now generally adopted plan for working the bowlder deposits in such a way as to free them as far as possible from the undesirable iron and alumina, chiefly present as adhering particles of clay, was, I believe, first suggested by myself in 1890. It consists in crushing all the big boulder rock to a sufficiently small size, and passing it, together with all the *débris* that comes from the mine, through washers of the type known as the Tennessee log-washer. After being

thus entirely freed from sand and clay, and passed through screens of various sizes, it is finally dried in open kilns, built up on logs of pine. The cost of production in this method of mining when economically carried out, as it is, for instance, in the washing-plants built by McLanahan & Stone, averages about $3.50 per ton and there is no waste of phosphate.

The land pebble phosphates have not yet been extensively worked, and as they are even more intimately mixed up with clays than the hard rock phosphate, there is still some doubt as to the most economical way of winning them. Some of the large concerns in Polk County employ a floating dipper-dredge set in a deep trench, which is deepened and extended as the deposit is removed. The entire mass of phosphate and matrix is brought up to the surface by the dredge, and, as in the case of the bowlder rock mines, is first dropped into a species of disintegrator or crusher. Thence it passes on into a revolving-washer mounted on the same structure. From the washer, the matrix and water return to the trench, while the clean nodules are carried by a spiral conveyor to a steam-heated dryer on a barge alongside. From the dryer they fall into a revolving-screen, which removes any remaining particles of adhering sand, and the now marketable phosphate is caught up by elevators and delivered on board railway-cars standing on a track parallel with the trench.

The exploitation of the "river pebble" is performed by means of a ten-inch centrifugal steam suction-pump placed upon a barge. The pipe of the pump having been adjusted by ropes and pulleys, is plunged ahead from the deck of the dredge into the water. The mixture of sand and phosphate sucked up by it is brought into revolving-screens of various degrees of fineness, whence the sand is washed back into the river. The cleaned pebbles can be discharged from the screen into scows at the rate of about twelve tons per hour, and the product is floated down to the drying-house, where it is taken up by an elevator and dried by hot air.

The total cost of raising, washing, drying, screening and loading "pebble" phosphates on cars, is stated to be $2 per

ton. As in the case of South Carolina, I have compiled the following table, showing the quantity of

PHOSPHATE (ROCK AND PEBBLE) OF ALL GRADES MINED BY THE LAND AND RIVER COMPANIES OF FLORIDA SINCE THE DISCOVERY OF THE DEPOSITS:

	Long Tons.
1888, year ending December 31st,	3,000
1889, " "	4,100
1890, " "	46,501
1891, " "	112,482
1892, " "	300,000

I have now finished what is, at the best, only a very brief and rough description of our phosphate beds, and I should probably best recognize your endurance by at once releasing you. While I freely recognize, however, that I shall be imposing on your good nature if I crave your indulgence for a few moments longer, I venture to do so because I much wish to touch upon two very important points bearing on my subject. The first of these relates to the practical use of phosphate of lime by the agriculturist, and the second to the desirability of universally adopting some correct and definite method for its analysis.

The phosphate miner, as we have seen, does not sell his product to the farmer, but to the manufacturers of fertilizers, who first grind it to an extreme fineness, and then mix the powder with about its own weight of weak sulphuric acid. Two out of the three molecules of lime originally combined with the phosphoric acid, being thus transformed into gypsum, a more or less soluble article is obtained which is the basis of all artificial fertilizers, and which is popularly known as superphosphate. The reason why this acidulated compound is preferred to the raw material is to be found in the generally admitted fact that tricalcium phosphate is very sparingly and very slowly soluble in the water of the soil, and that no element can penetrate into the interior of a plant unless it be in solution.

A great many attempts to use it as a direct fertilizer have demonstrated that the availability of raw mineral phosphate entirely depends upon the fineness of the powder to which it may be reduced, and the nature and composi-

tion of the soil in which it is to be employed, and it is a matter of the greatest difficulty to attain the requisite degree of disintegration by any sufficiently cheap mechanical means. In this respect we are, in fact, not very much further forward now than we were in 1857, when Liebig recognized the difficulty and proposed to solve it, by adopting a chemical method of decomposition which enabled the farmer to obtain practical results from the use of mineral phosphates within one year, instead of waiting three or four. That the chemical treatment does not in reality do anything more than break up the primary molecular formation of the tricalcic phosphate, is proved by the fact that superphosphate of lime is only soluble in water so long as the mono-calcic form retains its ascendency. Directly it reaches the soil, especially where carbonates are in abundance, the unsatisfied phosphoric acid unites with various earthly bases and becomes insoluble. To put it plainly therefore, the issue so far as the farmer is concerned, revolves upon a matter of time and of money. He might buy a ton of raw phosphates, ground as finely as possible, and containing, let us say, fifty-five per cent. of tricalcic phosphate for $10. If his land were tolerably acid, and this, of course, is seldom the case, he would get a rapid return, but if it were not, his raw phosphate would only decompose very slowly and he would have to wait three or four years before obtaining any appreciable results from his outlay. On the other hand, if he buys a ton of superphosphate for $20 containing only thirty per cent. of calcic phosphate made soluble, and applies it to a phosphate-barren soil, he produces the desired effects on his crop the same year. This is no hypothetical statement; I have seen the thing done over and over again in my own experience, and have satisfied myself that the true explanation of the different results is the one I have already given. The mere decomposition of the tricalcic phosphate into the acid salt ensures an absolute state of division which is maintained despite the subsequent reversion, and an intimate and immediate contact with the acid sap of a greater number of root hairs being thus facilitated, the ready ab

sorption of the dissolved phosphate by the plant, is naturally assured.

These views will be endorsed by all the officials of our agricultural experiment stations who have made the comparative use of the finely ground raw mineral phosphates and of superphosphate, and I believe that their results with the former have always varied in accordance with the nature of the soil in which the experiments were made; and have fully confirmed the conclusions formulated in 1857 by De Molon, who after very extensive trials of ground raw coprolite in many different departments of France, said that:

(1) Raw phosphate might be used with advantage in clayey, schistous, granitic and sandy soils rich in organic matter.

(2) If these soils were deficient in organic matter or had long been under cultivation, it might still be used on them in combination with animal manure.

(3) It may not be used with advantage in chalky or limestone soils.

I, therefore, take it that the term soluble, as applied to phosphate must be accepted in a relative sense, and I consider and have always urged that the use of both raw and manufactured articles is a matter which calls for intelligent discrimination on the part of the farmer. He might find that in one portion of his lands raw phosphates mixed with his compost heaps would soon dissolve and yield very profitable and rapid returns, while in another portion, owing to a different constitution of the soil, they would remain inert for an indefinite period.

In England and in Germany, a great deal of stress is laid by chemists upon the diffusibility of a water soluble superphosphate, and it is held that when rain falls after an application of such material, it distributes the phosphoric acid through the soil more perfectly than by any other method. The commercial value of superphosphate is, therefore, fixed in those countries upon the percentage of phosphoric acid which is soluble in cold water, and little or nothing is allowed for that portion which it may contain in the

"reverted" or water insoluble form. In this country, however, it has been conclusively shown by practical work that this very diffusibility of soluble phosphates ensures their rapid precipitation and reversion in the soil, and that this of itself proves "reverted" phosphate to be the true and only food for the plants. We therefore, accord to it the same commercial value as we do to water-soluble phosphate, and although our staple commercial grade of superphosphate, like that of England, France, Germany and Belgium, is from 10 per cent. to 13 per cent. of soluble phosphoric acid, we differ from those countries in that we are willing to accept a portion of that solubility in citrate of ammonia which dissolves "reverted" phosphates.

The persistent refusal by foreign chemists to recognize anything but water-soluble superphosphate, naturally causes the English and German manufacturers to demand a very low percentage of iron and alumina in their raw material. I say naturally, because it has been very clearly shown that when mineral phosphate is attacked by sulphuric acid, free phosphoric acid is formed, and that after a little while this commences to react upon any undecomposed material, and first of all upon the iron and alumina.

The insoluble compounds thus produced, cause a great loss of phosphoric acid to the manufacturer of water-soluble goods, and the custom of appraising the raw material according to its percentage of iron and alumina as well as its contents in phosphate of lime, hence becomes perfectly rational. From the commercial standpoint, every part of either iron or alumina present in raw phosphate will prevent the solubility of two parts of calcic phosphate in the mixing process, and there being no mineral phosphates absolutely free from these impurities, the European manufacturers have established a maximum standard of three per cent. as the limit of them to be tolerated without allowance. When the amount present exceeds this limit, they deduct the excess in the proportion of 2 to 1 as against the phosphate of lime.

Supposing for example, that a shipment turned out upon analysis to contain seventy-eight per cent. of phosphate and

three per cent. iron and alumina, the buyers would pay for each unit of phosphate without any reduction, but if the iron and alumina attained say four and one-half per cent., they would claim an allowance of three units of phosphate of lime and would only pay for seventy-five, instead of seventy-eight per cent., of the latter. The urgency for the most accurate analysis of all phosphate that is shipped abroad, being under these circumstances amply demonstrated, it is a fact to be regretted that up to the present time such accuracy has not been attained, and that the results of foreign buyers' chemists are anything but concordant with those of our producers' chemists on this side.

To the uninitiated this is an unaccountable fact, and it is all too commonly explained by the vulgar conclusion that analytical chemistry is neither reliable nor exact, and that it cannot in practice, substantiate scientific theory.

Why, it is asked, should the chemist, in the South—who is perfectly conscientious and has no interest to deceive—differ materially in his findings from a chemist, equally but no more honest and trustworthy, working at the East or North.

Nothing could cast a greater aspersion on the highest of professions than this state of affairs, and yet nothing on earth could be more easily and perfectly remedied. All that is necessary is for the chemists to come together and agree upon certain methods of sampling, and to invite purchasers and sellers of phosphates and manures to regulate their settlements on the basis of a prescribed analysis. In this manner all divergency of results should disappear, and, all other conditions being equal, any further discrepancies would be attributable only to incompetency or bad faith. The chemist's hand, is, of course, not always steady, nor is the eye always accurate, and while we are liable to physical defects and weaknesses, we shall never be free from mistakes; but it is nevertheless a fact which has forced itself upon all thinking men, that uniformity in manipulation is the prime factor in the attainment of uniform results, and nowhere is such uniformity a *sine qua non* as in the laboratory.

In my own practice I have used a method of determining the percentage of total iron and alumina in any given sample of mineral phosphate, which has been submitted to the most elaborate and painstaking investigation and comparisons by my associate Dr. L. Saarbach.

Its results seem to accord very closely indeed with those of the most prominent English and German chemists, and for this reason I take the liberty of presenting it here in the hope that its adoption may become general in commercial laboratories.

Two grammes of dried ore are very accurately weighed out and placed in a porcelain dish with twenty cubic centimeters of hydrochloric acid. The dish is placed upon a hot iron plate, covered with a watch-glass, and the contents are allowed to slowly evaporate to dryness, care being taken to avoid any spurting and consequent loss. As soon as it is quite dry, the residue is moistened with pure nitric acid in order to oxidize the iron present, and again evaporated to complete dryness. The dish is now allowed to cool and the residue is well stirred up with twenty cubic centimeters of pure hydrochloric acid, and allowed to stand for ten minutes in a warm place until it is quite disintegrated. The acid is then diluted, the whole is filtered, and the dish and the filter are very carefully washed until the filtrate measures 250 cubic centimeters. The residue on the filter must be quite white after calcination. Half of the filtrate (125 cubic centimeters) is now made distinctly alkaline by the addition of ammonia and just sufficient acetic acid, pure and concentrated, is stirred into it to produce distinct redness on very sensitive litmus paper. After being allowed to stand until perfectly cold the mixture is filtered and the beaker and residue are very carefully washed.

The substance on the filter is now dissolved by a little hot fifty-per-cent. solution of hydrochloric acid; the filter paper is washed until the wash water has a neutral reaction and the filtrate is made up to about 125 cubic centimeters. A few drops of sodium phosphate solution are now added; the liquid is then made alkaline with ammonia in slight excess; and after being made sufficiently acid with pure concen-

trated acetic acid as in the first operation, is well stirred up, and again allowed to stand until absolutely cold. It is then filtered on an ashless filter, and the filter is well washed with boiling water.

When the washing is complete, the filter is placed in the oven and dried, after which it is calcined with its contents; placed in the dessicator, and, when cold, the residue is weighed as phosphates of iron and alumina in one gramme of the material.

The weight of the combined phosphates having been carefully noted, they are dissolved in boiling dilute hydrochloric acid and the solution is filtered into a 100 cubic centimeter flask and washed up to the mark.

No residue should remain on the filter save perhaps a speck or two of carbon resulting from the recent incineration. In one-half of the cooled filtrate, the phosphoric anhydride is determined by the official molydate method. The resulting magnesium pyro-phosphate ($Mg_2 P_2 O_7$) is calculated to phosphoric anhydride ($P_2 O_5$) in one gramme of the combined phosphates by the factor ·6396.

The remaining half of the filtrate is warmed with a small piece of zinc in a flask fitted with a bunsen valve. When the iron is completely reduced and gives no trace of pink coloration with potassium sulphocyanate, the liquid is cooled, about one gram of magnesium sulphate is dissolved in it, and is then titrated with $\frac{1}{10}$ N. permanganate solution, every cubic centimeter of which equals ·00080 ferric oxide.

Two out of three constituents of the mixed phosphates having been thus accurately determined, the third, which is the alumina, is easily arrived at by difference.

Within the past few years, the rapid development of the fertilizer industry has led to the introdroduction of a concentrated material known as "High-grade-supers," which is made to contain about forty-five per cent. of phosphoric anhydride (P_2O_5) in a "water" and "citrate" soluble form, and which should in my opinion soon entirely supplant the weaker "supers" in general use. The plan upon which it is produced is perfectly scientific and rational, since it consists in dispensing with oil of vitrol and using in its place phosphoric acid as the solvent of the raw phosphate.

I have mentioned that in the manufacture of superphosphates as now carried out, the desired solubility, either in water or in citrate of ammonia, is attained at the cost of doubling the bulk of the raw material by the addition of sulphuric acid, which practically serves no other purpose and has no other value than that of a dissolvent. If such raw material, therefore, contain sixty per cent. of tricalcic phosphate, the "super" can only contain thirty per cent., and this, from the agricultural consumers standpoint, is certainly an anomaly, and, apart from any question of solubility, must remain so for two reasons:

(1) A ton of sixty per cent. phosphate of lime, finely ground, but insoluble in water or citrate of ammonia, can be purchased at some central point for, say $10.

(2) A ton of superphosphate, containing only thirty per cent. phosphate of lime, cannot be purchased at the same spot for less than $15.

In the one case, freight is paid upon only forty per cent. of waste material, whereas in the other, it is paid upon seventy per cent. of practically valueless matter.

That a legitimate profit should attach to the manipulation of an inert, and its transformation into an active body, is beyond question, but I cannot see why such enormous and unreasonable benefit should be derived from the trade in fertilizers by the railroad companies. If it were for no other object therefore, than the reduction of such detrimental freight charges to a minimum limit, I think it is well worth while to consider briefly the practicability of superseding the old method of manufacture.

The reactions involved in the process of superphosphate mixing have served to demonstrate that the cheapest and best known method of making liquid phosphoric acid from calcic phosphates, is by driving it from its combination with lime by means of the stronger oil of vitriol, and by utilizing many low-grade phosphates which now, for lack of a sufficiently cheap freight, have practically no market value. The only essential conditions to the manufacture are:

(*A*) That the material used shall contain a minimum of

carbonate of lime, in order that no unnecessary excess of the sulphuric acid be required for its decomposition.

(*B*) That it shall contain as small a percentage as possible of any combination of iron and alumina, since both of these bodies contribute to the formation of a gelatinous mass that seriously interferes with the course of the operations.

If the exact chemical composition of the raw phosphate is known, the quantity of sulphuric acid necessary to insure the desired dissociation of all the phosphoric acid from the various bases present is very readily calculated.

The operations are conducted in large tanks made of suitable wood, lined with lead and provided with agitators The required quantity of sulphuric acid, say, for example 2,000 pounds of 50° B. strength, is mixed in each tank with sufficient water to reduce it to a density of 14° B The agitators being in active motion, a sufficient quantity, say, 2,000 pounds of finely ground phosphate, is slowly added to each tank and stirring is continued for five hours, open steam being occasionally blown in by an injector through the side of the tank in order to keep the mixture quite hot.

When the five hours have expired, the cream from each tank is run off into filters made from large wooden vessels lined with lead and provided with false bottoms, where the hydrated sulphate of lime separates from the solution of phosphoric acid. The latter passes through the filter as a bright straw-colored fluid, of a gravity which, commencing at about 12° B., gradually becomes reduced by careful washing to 1° B.

The exercise of ordinary care and precautions prevents all cracks from being formed on the surface of the gypsum contained in the filters, and the lixiviation of the mass is stopped directly the gravity of the filtrate reaches 1° B. The hydrated sulphate of lime is now raked together into the center of the filters to drain, and is finally carried to the dump, while the last runnings from the filters, which are too weak for economical concentration, are used to dilute the strong sulphuric acid required for subsequent operations.

The filtered phosphoric acid liquor is pumped into an elevated tank, and thence it runs by gravitation to a series of leaden evaporators of any convenient form of construction, heated either by direct fire from the top or from the bottom, or by waste steam from boilers.

During the progress of the evaporation the acid solution practically deposits all its sulphate of lime, and it finally attains a density of about 45° B. At this strength it should contain about forty-five per cent. of phosphoric anhydride, with only a mere trace of lime, magnesia, and iron and alumina, and is now ready for use in place of sulphuric acid in the manufacture of soluble and assimilable phosphates. Its mixture with the raw phosphate can be effected in the usual superphosphate mixers, on the same system of calculation and by the same method of manipulation as are now used with oil of vitrol, and it very soon sets into a porous mass, which, although not very dry, is sufficiently stiff to be easily dug out. This mass is cut up into pieces of reasonable size and dried by hot air, in any form of shed that will facilitate effective and rapid work. Directly it is sufficiently dry for the market, it is put through a disintegrator and filled into bags.

If you will compare this material with our present staple superphosphate, which barely contains the equivalent of thirty per cent. of bone phosphate of lime made soluble, you will find that, in addition to its lower manufacturing cost, it contains the equivalent of ninety-nine per cent., or more than three times as much bone phosphate of lime, made equally as soluble and available. It could, therefore, be distributed at an economy of two-thirds of the freight now actually paid for useless material, and you will agree with me that this is a consideration of the highest consequence, since the world must have phosphate, and since our raw material, while it is of the best quality known, is confined to an area somewhat remote from the large mass of consumers.

The present results of phosphate mining enterprises have been very disappointing and discouraging, but I think that this should only spur us on to exercise all our ingenuity in

order to make our products more available for the world's needs. As the farmers become more enlightened they will eagerly seize all means of wealth that can be readily and cheaply brought to their doors, and will be only too ready to apply to their impoverished fields the sustenance that phosphate will impart.

I do not consider that any more important duty rests upon our agricultural chemists than that of disseminating practical scientific knowledge, and of stimulating the application of that knowledge for the benefit of exhausted hands. This mission will not merely prove commercially profitable from the standpoint of manufacture and trade, but will at the same time fully satisfy all the demands of philanthropy; for, as Dean Swift has said: "Whoever can make two ears of corn, or two blades of grass, to grow upon one spot of ground where only one grew before, will deserve better of mankind, and do more essential service to his country, than the whole race of politicians put together."

THE LAW OF INVENTION.*

By HORACE PETTIT, of the Philadelphia Bar.

LECTURE I.

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:—The race of inventors is a new race. As a race it may be said to date its existence and origin from the beginning of the nineteenth century. Each century, as it rolls around, becomes known and noted for one thing more than another, and goes down to history having attached to it some special characteristic. Prior to the beginning of the present century there was no race of inventors; a few scattering progenitors existed through the earlier centuries, plying a desultory kind of a trade, securing for their efforts sufficient discouragement and expressions of contempt and ardor-

* Two lectures delivered before the Franklin Institute, November 10, 1893.

dampening receptions to have extinguished the brightest genius. The race was only commencing to develop when Watt produced his engine. He was a curiosity. Iconoclasts, history shows us, were always deemed cranks. For declaring that the world moved, Galileo was convicted in 1633 of heresy. Men who did or declared anything out of the usual recognized order of things were considered to be in league with the devil. Had not Ferdinand and Isabella been in advance of their times, the World's Fair celebration of the four hundredth anniversary of the discovery of America would probably not have been held until a much later date.

Start at the beginning of this century and go back, decade by decade, century by century, and we will find only a scattering few who rose to the dignity of inventor—and they decreased as the square of the distance. What was invented or discovered by the early forefathers of invention was not then followed up nor developed. The inventors died and passed away, and with them their discoveries or theories—there was no one to follow them up. As the centuries rolled on, however, greater development was discernible in isolated instances.

The Chinese were far ahead of their day and generation in the world of discovery and invention in centuries gone by; but the Chinese race is, and always has been, peculiarly constituted—the Chinese did not, and do not, develop—they copy—they do not progress. Dr. Strong, in his recent work, "The New Era" says: "It would seem as though the Chinese were all run in the same mould and each generation were a weary repetition of the preceding. There is a uniformity which is favorable to far-reaching organization, but fatal to individuality; and where there is no individuality there can be no progress. China has stood for many years with her back to the future." There was no development here. But development did come slowly, however, to other countries. The knock which Sir Isaac Newton is said to have received on the head by the falling apple seemed not only to stir him, but also to set others to thinking. Here was a natural law which had existed since the creation, and yet it

V.1
189

seems not to have been fully realized and appreciated until about 1666.

Is it not strange that, although all the laws of nature as they exist to-day have existed since the beginning of time, it was not until this century that they have been measurably understood, or the powers and forces through which they found expression, applied practically in an advanced degree to commerce and the arts? Given the dissemination of knowledge through the medium of the printing press, the practical application of steam for motor purposes, the development of metallurgical processes and the harnessing of electricity to instant message transmission and to the production of power, and we have a state of affairs which renders possible the development of the inventive faculties at a rate which increases with astonishing rapidity. Its development may be likened to the increasing velocity of travel of a falling body.

To the latter half of this century has been reserved the distinction and honor of achieving more in the line of invention and discovery than all the ages of past history combined. This may be truly said to be the "Era of Invention."

To past centuries the word "invention" had little meaning; to our contemporaries it is a word of the most significant importance. To consider the subject practically, we must consider it from its legal standpoint. It will be appreciated that the time allotted to two brief papers must necessarily involve a somewhat cursory consideration. A subject, therefore, which involves so much can only be briefly touched upon, and only in some of its principal branches. The question, "What is Invention?" will have to be considered somewhat at length, and will occupy the larger portion of this evening's paper.

SOVEREIGN RIGHTS.

It will be unnecessary to consider the common law as it existed in England or in this country prior to any legislative enactment relative to patents for inventions, except, perhaps, in a most cursory manner, as no right of property

existed in an invention or discovery at common law. There is no doubt that at common law the prerogative existed in the king to grant to his subjects protection, at least for a limited period of time, for their inventions. But no *right of property* in an invention existed at common law. Previous to legislative enactment—without the special exercise of the prerogative on the part of the king—the inventor or discoverer had no right of property in his invention or discovery, and after he had once enlightened the public, or any individual, as to its construction or existence, he was powerless to prevent others from manufacturing, selling or using to any extent that they saw fit. The prerogative of the king was, of course, only exercised at his will, large sums being frequently demanded as the price of its purchase.

Prior to 1623, the prerogative of the sovereigns of England in granting monopolies of all kinds had been abused to a very large extent for the purposes of raising revenue to meet the expenses of the crown. This right, in the hands especially of an unscrupulous sovereign, worked disastrous results upon trade and commerce; the favored few secured monopolies in particular lines of business, to the exclusion of all others; shops and factories, which, perhaps, had been established after many years of arduous toil, and by the outlay of large sums of money, were in a day closed down by the seal of the sovereign placed upon a piece of parchment, granting to one favored courtier or subject the exclusive right to engage in that particular line of trade or branch of commerce. From about 1261 to the time of the reign of Edward VI (1551), the commerce of England was almost entirely in the hands of foreigners—especially those from the Hanse towns, or Easterlings, as they were called, to whom Henry III had granted special privileges and erected into a corporation in order to induce them to settle in London. During this period they were maintained and protected by the crown to the exclusion of all others. Hume, Chap. xxxv, says: "So ignorant were the English of commerce, that this company, usually denominated the merchants of the 'stil-yard,' engrossed even down to the

reign of Edward VI almost the whole trade of the kingdom." Naturally, great abuse of their privileges arose, to the great detriment of the English citizens. In A. D. 1551, the privileges were very much restricted, and thereafter the industries of London and England began to thrive in the hands of the citizens. But other abuses began to creep in which were equally as injurious to trade generally as when it was the monopoly of the foreigners.

The royal prerogative was given or bartered for mercenary purposes, and the bulk of the trade of England began to be absorbed by the few. (Robinson, on Patents, vol. 1, p. 6.)

The reign of Elizabeth was notorious. The necessaries of life were monopolized, under royal grant, by a few; salt, for instance, which had been sold at six pence per bushel, was raised to fourteen shillings; oil, starch, vinegar, paper, were controlled by the monopolists, who had the arbitrary right thrown in with the grant to search stores and private property where they suspected any alleged infringing goods to be stored. (Hume, c. xliv.)

We talk about the greed of corporate monopolies and trusts of the present day, but their attempts, let me say, have been comparatively futile as compared with those of our illustrious ancestors of 1600. Even after James I tried to alleviate the matter by rescinding the rights of the monopolies under grant, a gigantic trust was formed consisting of prominent merchants of London, who combined together to control the foreign trade, raising or lowering the prices of imports at will.

If any of our Sugar or Standard Oil Trusts should have attempted to apply for a patent to protect their processes of dealing, it is quite clear their claim would have been invalidated by the citation of this anticipating reference. If we only reflected we would ofttimes be very much chagrined and taken aback by discovering that in many things we are but weak imitators of the virtues and vices of our illustrious ancestors.

Before Parliament saw fit to take any action in the matter of these abuses of the royal prerogative, private subjects carried the question before the court of the King's Bench,

in the shape of an infringement suit, by way of defence. It was not contended in the suit referred to that the king had not the right to grant exclusive privileges for limited periods of time, where the grantee, by his own charge and industry, or his own wit or invention, brought any new trade into the realm, or any engine tending to the furtherance of the trade that never was used before—and that for the good of the realm—in such cases it is clear that the king could grant a monopoly patent for some reasonable time until the subjects learned the same, in consideration of the good that he brought by his invention to the Commonwealth; otherwise not.

The case referred to is that of Darcy *vs.* Allin (1602), (Noy, Rep., 173), (Coke R., 84 b.). This case, as well as that of the subsequent case of the cloth-workers of Ipswick, which are referred to in most of the text-books (1615, Godbolt, 252; 1 Abb. P. C.) were both cases in the King's Bench where the patents or grants of monopoly were defeated, and the validity of the letters-patent was denied.

The case of Darcy *vs.* Allin was an action on the case upon a grant made by Queen Elizabeth in the thirtieth year of her reign, to one Ralph Bowes, for the exclusive privilege of making, importing and selling playing cards for the period of twelve years, which had subsequently been extended to the plaintiff, Darcy, an assignee of Bowes. Darcy brought the suit against Allin to restrain him from manufacturing playing cards. It was not contended that Bowes, the original grantee from the Queen, was the inventor of playing cards, but that under the grant made to him, by virtue of the Queen's prerogative, he had the exclusive monopoly of the trade in playing cards for the period stated. In other words, it was not contended that Bowes conceived anything, or discovered or invented anything, which had not been known before. The defendant denied the right of the Queen to make such an exclusive grant, and contended substantially that the liberties of the subjects in this regard were preserved and maintained to the subjects by Magna Charta.

The general question, however, of prior knowledge or

use was also discussed. It was contended, also, that even where letters-patent had been granted by the sovereign for alleged inventions they were invalidated when it should be shown that the particular article protected had been known and used in the kingdom before, as where a monopoly patent was granted in ninth Elizabeth to a Mr. Hastings for making frisadoes, such as it was averred had never been made in England before, but which he had introduced from Haarlem and Amsterdam, beyond the seas, a penalty being provided in case of any infringement thereof. The defendant in this case escaped, having shown that baize, very like Mr. Hastings' *frisadoes*, was made in England before the date of Mr. Hastings' patent. In another case, that of a monopoly patent granted for knives with bone hafts and plates of lattin, to Mr. Matthey, of Fleetbridge, he being alleged to have brought the same from "beyond the seas." Here also, other knives, so like Mr. Matthey's, were shown to have been used in England before, that the defendants were not restrained. Humphrey's monopoly patent for a sieve, or instrument for melting lead, was judged invalid on the ground that it had been used before in Derbyshire and at Mendiff in the West Country.

Darcy *vs.* Allin was decided in favor of the defendant and against the right of the sovereign to grant an exclusive monopoly for anything other than an *invention* or *importation*, as also in the cloth-workers' case before cited.

STATUTE OF MONOPOLIES.

This evil of monopolies becoming more and more apparent, the matter was substantially cured and corrected, at least as far as possible, in 1623, by the Statute of Monopolies, 21 James I, (c. 3, s. 6), whereby it was enacted that all monopolies were contrary to the laws of England, and were, and should be, null and void.

Section 6, however, contained an apparent exception as follows, viz.: "Provided also, and be it declared and enacted: That any declaration before mentioned shall not extend to any letters-patent and grants of privilege for the term of fourteen years, or under, hereafter to be made of

the sole working or making of any manner of new manufactures within this realm, to the true and first inventor and inventors of such manufactures, which others, at the time of making such letters-patent and grant, shall not use, so as also they be not contrary to the law nor mischievous to the State by raising prices of commodities at home or hurt of trade, or generally inconvenient; the said fourteen years to be accounted from the date of the first letters-patent or grant of such privilege, hereafter to be made; but that the same shall be of such force as they should be, if this act had never been made, and of none other."

The effect of this clause of the Statute of Monopolies was not to restrict the king's prerogative, as it existed prior to the passage of the act in relation to patents for inventions, but to define his right to grant patents for the term of fourteen years, for the sale, making or working of any manufacture not hurtful, and "shall be of such force as they should be if this act had never been made, and of none other."

Mr. Curtis, in his introduction to his work on the "Law of Patents," says, in his preliminary observations:

"A patent for a useful invention is not, under our law, or the law of England, a grant of a monopoly in the sense of the old common law. It is the grant by the government to the author of a new and useful invention, of the exclusive right, for a term of years, of practising that invention. The consideration for which this grant is made by the public is the benefit to society resulting from the invention; which benefit flows from the inventor to the public in two forms, *first*, by the immediate practice of the invention under the patent; and, *secondly*, by the practice of the invention, or the opportunity to practise it, which becomes the property of the public on the expiration of the patent."

It is unnecessary here, in this brief paper, to further consider the Statute of Monopolies, the cause for its passage, or its effect. The subject is elaborately considered in numerous text-books upon patents, and notably so in "Robinson on Patents," Vol. I. Suffice it to say, that Sec. 6 of this Statute determined by special grant the right of

the inventor to protection for his invention for a limited period of time at the hands of the sovereign.

THE LAW OF PATENTS IN THE UNITED STATES.

Most civilized countries have made provision for the protection of inventors in their inventions. This moral right of the inventor of exclusive property to his invention for a limited period of time, and the benefit which is to be derived by the public by such stimulus to invention, has been fully recognized.

In the United States the inventor's right is now based solely upon the Constitution of the United States and Federal legislation. I do not mean to say that the individual States have no right to grant patent privileges to their citizens, or to those residing within the State; on the contrary, there is high authority for the proposition that the individual States have still this right should they desire to exercise it.

The Federal Government has only the powers and privileges which have been granted it by the individual States or by the people, which powers and privileges are derived from the Constitution of the United States.

The Constitution, Article I, Sec. 8, provides that "The Congress shall have power . . . to promote the progress of science and useful arts by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries."

In the case of Martin *vs.* Hunter's Lessee (1 Wharton R., 304), it was held: "The Government of the United States can claim no powers which are not granted to it by the Constitution; and the powers actually granted must be such as are expressly given, or given by necessary implication." This doctrine does not apply to the independent States. Their powers are sovereign powers, but limited by the powers which they have conferred upon the Federal Government through the Constitution.

Daniel Webster said, with much force: "Our Constitution is one of enumeration, and not of description."

This grant of power by the States to the Federal Govern-

ment, it is contended by Chancellor Kent, does not, by the terms of the grant contained in the Constitution, confer or imply an *exclusive* grant therefor; that is, it does not confer such an exclusive grant as to preclude the individual States from granting through the proper channel protection to inventors, if the State should see fit to do so.

Bearing upon this question of the concurrent right of individual States to grant patents for inventions, Chief Justice Kent, in the case of Livingstone and Fulton *vs.* Van Ingen (1812) (9th Johns., 507), held as follows:

"If the grant is not inconsistent with the power of Congress to regulate commerce, there is as little pretence to hold it repugnant to the power to grant patents. That power only secures, for a limited period of time, to authors and inventors, the exclusive privilege to their writings and discoveries; and as it is not granted by exclusive words to the United States, nor prohibited to the individual States, it is a concurrent power which may be exercised by the States in a variety of cases, without any infringement of the Congressional power. A State cannot take away from an individual his patent right and render it common to all citizens. This would contravene the Act of Congress, and would be therefore unlawful."

We should want no better authority than that of Chancellor Kent. Were the authority less eminent, we should accept the doctrine with much caution.

SECTION 4886.

It is unnecessary to follow this question of State rights further; let us proceed to a more intimate consideration of the law and the cases. By the Constitution the power was given to *Congress;* it was incumbent upon Congress to act.

The acts of Congress passed since the date of the Federal Constitution relative to patents are numerous. These numerous acts we will not pause here to separately consider, but must pass immediately to the law as it is contained in the Revised Statutes of the United States.

Section 4886 of the Revised Statutes of the United States is as follows:

"Any person who has invented or discovered any new and useful art, machine, manufacture or composition of matter, or any new and useful improvement thereof, not known or used by others in this country, and not patented or described in any printed publication in this or any foreign country, before his invention or discovery thereof, and not in public use or on sale more than two years prior to his application, unless the same has proved to have been abandoned, may, upon payment of the fees required by law, and other due proceedings had, obtain a patent therefor."

This brief section embodies substantially the backbone of the patent law of the United States as it exists to-day, and yet these few lines are required to be interpreted and re-interpreted in almost every suit litigated involving the patentability of an invention. Volumes of decisions have been written upon it, and volumes will continue to be written so long as it or any like statute exists.

It may safely be said that in no branch of litigation does each case "stand upon its own bottom" so thoroughly and so completely, and require such independent review as do the cases involved in patent litigation.

This brief section absolutely defines who is entitled to a patent, and it defines what things are the subjects of patents, which no court in the United States can gainsay. But the courts interpret. Many cases are on the border line, which renders just interpretation frequently exceedingly difficult.

What is that "border line" of invention upon which so many litigated patents serenely rest? It is as marked and well defined as that imaginary line drawn in the fair sex, on the one side of which the girl is a blushing bud, on the other a full-blown rose. Where are you going to draw the line of demarcation? Ask of the highest Court of Appeals, and perchance it will give you no fixed infallible rule. Know that line, then you will know what is and what is not *patentable invention.*

WHAT IS PATENTABLE INVENTION?

I desire at this point to say that even now in *doubtful* litigated patents, the practical commercial results of the invention serve as a powerful guide to the courts, as it has done in the earlier times, in determining the question of *patentability*. A careful examination of the cases bears out this view.

Where a mere doubt exists at the time of application regarding the novelty and patentability of an invention, it is generally resolved, as it should be, in favor of the applicant, and the courts, when subsequently called upon to pass upon such patent, will, as they should, be considerably guided, where such a doubt as to patentability still exists, by the fact that the invention in question has proved commercially successful.

THE TELEPHONE CASES.

As a usual rule, however, in the class of cases just referred to, it will be found that where an invention has proved successful commercially, there is some *inherent reason* for it residing in the invention itself. This may be illustrated, for instance, by the celebrated telephone cases, where a mass of alleged anticipatory testimony, some of it very strong, was produced. It is true that the credibility of some of the testimony was very much doubted by the court, but Mr. Bell had in his favor throughout the whole proceedings the fact that he had described a successful operative means of transferring to, or impressing upon, an undulatory current of electricity, the vibration of air produced by the human voice in articulate speech, in such a way that the speech was carried to and received by a listener at a distance on the line of the current. Never before had such an invention been given to the public; it was one of the greatest inventions of the age, and naturally it would have taken very strong evidence of anticipation to have defeated his patent (American Bell Telephone Cases, 126 U. S., 863).

The Bell Company rested their entire case upon the fifth claim of the Bell patent, which is as follows: "The method

of, and apparatus for, transmitting vocal or other sounds telegraphically, as herein described, by causing electrical undulations similar in form to the vibrations of the air accompanying the said vocal or other sounds, substantially as set forth."

It is interesting to note that when Bell applied for his patent he had never actually transmitted telegraphically-spoken words so that they could be distinctly heard and understood at the receiving end of his line; but as stated by Mr. Chief Justice Waite, in delivering the opinion of the court, "In his specification he did describe accurately, and with admirable clearness, his process; that is to say, the exact electrical condition that must be created to accomplish his purpose; and he also described, with sufficient precision to enable one of ordinary skill in such matters to make it, a form of apparatus which, if used in the way pointed out, would produce the required effect, receive the words, and carry them to and deliver them at the appointed place. The particular instrument which he had and which he used in his experiments did not, under the circumstances in which it was tried, reproduce the words spoken, so that they could be clearly understood; but the proof is abundant, and of the most convincing character, that other instruments, carefully constructed and made exactly in accordance with the specification, without any additions whatever, have operated and will operate successfully."

It will thus be seen that, although Bell did not give to the public at the date of his application for a patent, a commercially operative device, and never up to that time had constructed one himself, he did, nevertheless, describe and claim such a device in his application as would enable others skilled in the art to make a successful operative commercial device. Perhaps it may safely be said that at the date of Bell's application he had not been as successful in his actual experiments as some of those who had experimented before him, but they had never completed, either in an actual device, or upon paper, the invention to the extent to which Bell had perfected it.

Mr. Chief Justice Waite said, *inter alia:* "Some witnesses

have testified that they were unable to do it (construct an apparatus from Bell's patent); this shows that they, with the particular apparatus which they had, and the skill they employed in its use, were not successful; not that others, with another apparatus, perhaps more carefully constructed, or more skilfully applied, would necessarily fail. As was said in Webster Loom Company *vs.* Higgins (105 U. S., 580,586), 'when the question is whether a thing can be done or not, it is always easy to find persons ready to show how not to do,' if one succeeds that is enough, no matter how many others fail. . . . The law does not require that a discoverer or inventor, in order to get a patent for a process, must have succeeded in bringing his art to the highest degree of perfection. It is enough if he describes his method with sufficient clearness and precision to enable those skilled in the matter to understand what the process is, and if he points out some practicable way to put it into operation. This Bell did."

EDISON LAMP.

Another illustration which may be used in this connection is the Edison incandescent electric lamp (U. S. Patent No. 223,898, Jan. 27, 1880). This has gone most largely into commercial use, and there are now few small towns in the United States, as well as in Europe, which have not installed some of these incandescent electric lamps.

Mr. Edison had his patent sustained in two or three of the Circuit Courts of the United States (Edison Electric Light Company *vs.* U. S. Electric Lighting Company, 47 Fed. Rep., 454, Dist. N. Y., affirmed, 52 Fed. Rep., 300; Id. *vs.* Beacon Vacuum Pump and Electrical Company, 54 Fed. Rep., 678, Dist. Mass.) In one or two of the later cases a new defence, in the shape of an alleged anticipation of the Edison patent has been presented, and very elaborately, in the case of the Edison Electric Light Company *vs.* The Columbia Incandescent Lamp Company (65 Off. Gaz., 133, East Dist. of Missouri) on motion for preliminary injunction. In this case the court refused the preliminary injunction. Without having had the pleasure of examining the evidence

presented upon the motion for preliminary injunction, I understand, from the data given in the report, and from other unofficial data, that the defence alleged is, substantially, that one Henry Goebel, a German by birth, came to this country prior to 1854, having acquired some knowledge of electricity abroad. He opened a small shop in the lower part of New York City and plied a desultory kind of a trade in repairing watches, telescopes and optical instruments; that before coming to this country he had become in some manner associated with a gentleman familiar with electricity, who suggested to him the idea of producing light by means of electricity through the medium of a film to be rendered incandescent in a vacuum bulb; and that after opening his shop in New York he spent some of his leisure time in carrying out this idea, and did make, as early as 1854, out of fine strips of bamboo, films which he encased in a glass globe rendered air-tight, and by connecting a current from a battery, or other source, produced what was substantially an incandescent light, his lamp being different in form, but in all essential features the same as those now in general use.

Goebel exhibited this in his shop window as a matter of curiosity, and also on the streets of New York, at the base of a large telescope, which he took around in the evenings to allow passers-by, at a small price, to view the stars; the incandescent lamp here also operated as a curiosity, or means of attracting attention to his telescope. It appears that Goebel has recently made several lamps of the form and with the material and tools formerly used by him. "These lamps," said Judge Hallett, in the Missouri case, "were tested by men of skill and experience in such matters, and they were found to be reasonably effective. They are not so good as the lamps in common use; but they can be operated and they give reasonable service in time and capacity of light."

The Judge did not appear to think Goebel's testimony to be at all improbable, and that it was supported at many points by witnesses of good repute, who spoke with precision and apparently with deliberation.

This case is peculiar. The invention might have been for practical purposes completed by Goebel in 1854—we may say perfected—and yet not have gone into general use or have been taken up by the public because it required something outside of itself to bring it into general use—a commercially practicable current generator, which was not perfected until a much later date. If defendant's contention is correct, Goebel's lamp of 1854, applied to the present dynamo, would have successfully operated, and containing, as contended, all the essential features of the claim of the Edison, 1880, patent, would defeat the claim.

If in this case defendant's contention is correct that the Goebel lamp did contain all the essential elements of the Edison lamp, there being no substantial difference between the two, the fact of Edison's commercial success, and of supplying the public want, would not enter into the consideration of the case, as this was due, not to perfection or change in invention, but to an *extraneous fact*, namely, the coming into existence of the commercial dynamo. On the other hand, it might be urged, why did Goebel not bring forth his invention immediately upon the introduction of the commercial dynamo, and not wait until thirteen years after Edison secured his patent before the Goebel claims should be pressed. Numerous explanations might be made to this contention. If the testimony to be produced upon final hearing substantiates that which appears to have been produced by affidavits upon the motion for preliminary injunction, it would certainly look as though Mr. Edison would be deprived of the credit of being the inventor of the incandescent lamp. All engaged in patent practice, however, know that it is easier to defeat a motion for preliminary injunction and cast the time-worn "reasonable doubt" upon validity, than to ultimately sustain it upon final hearing.

Section 4886 says "any person" is entitled to a patent who has invented or discovered, etc. This leaves no doubt that any one who answers the other requirements is entitled to a patent, be the inventor native or foreign born, black or white, adult or minor, male or female. It was formerly not so in the United States. Aliens were discriminated against;

but through sundry acts of Congress the *alien* was placed upon a par with the native born. Should an inventor die before obtaining protection by letters-patent, his invention may be patented by his executors or administrators, with full protection of his rights.

The wording of this section of the act is very plain, but the adaptation of it to the particular cases as they arise is most difficult. The section of the act says: "Any person who has invented. or discovered, any new and useful art, machine, manufacture or composition of matter," etc., is entitled to a patent. The section of the act does not say what invention is; that question is left to the Patent Office in the *first* instance, and to the courts *ultimately*. As there appears to be no fixed rule by which invention is to be determined, it is one of the most difficult questions which a patent attorney has to solve, to successfully decide, especially in *border line* cases, what is, and what is not, invention; the court has the last guess.

Mr. Walker, in his work on patents, section 24, says: "It is seen to remain true that the ideal line which separates things invented from things otherwise produced has never been completely defined or described. There is no affirmative rule by which to determine the presence or absence of invention in every case" (citing Dunbar *vs.* Field Tack Co., 4 Ban. and Ard., 519).

Robinson on Patents, Vol. I, section 59, says it is perhaps incapable of exact definition, and the line between it and what the patent law regards as a mere imitation is very difficult to draw.

Mr. Edward S. Renwick, who may be said to have had the largest experience of any man (living or dead) as an expert in patent cases, in his recent work, entitled, "Patentable Inventions," says, p. 1, section 2: "As to what constitutes invention the following dictum was pronounced, in 1880, by the United States Supreme Court (Pearce *vs.* Mulford, 102, U. S., 112, 26, L. ed. 93): 'but all improvement is not invention and entitled to protection as such. Thus to entitle it, it must be the product of some exercise of the inventive faculties.'" "What these faculties are," says Mr.

Renwick, "or how they are to be distinguished from the constructive faculty of the mind, is a matter that is left by the court in profound obscurity. No two persons can agree as to the line of demarcation between the two faculties, because from the variations in the characters of the minds of men, their differences in training and in experience, a change which to one mind appears to have involved the exercise of the so-called inventive faculty, is thought by another (*after* the event) to have been the result of merely the constructive faculty or of mechanical skill. Hence, to test the existence of invention by the assumption of the exercise of mental faculties by which it has been produced, and which are indefinable, amounts simply to an attempted determination of a truth by mere judicial opinion, without reliance upon evidence and without recourse to rules by which a just conclusion can be reached."

This, certainly, of itself, would leave the subject in the state of chaos. Mr. Renwick very naturally deplores this condition of affairs, viewed, as he views them, and fears that the creation of the present nine appellate courts will tend to multiply the constructions of the law as to what constitutes invention, rendering it more diverse than even heretofore, unless these courts shall decide upon *some rule* by which invention can be determined. By reason of Mr. Renwick's large experience as a patent expert and solicitor of patents (although, I believe, he has never been admitted to the bar), his opinion is entitled to much respect, and it would be with great caution that any one would attempt to criticise the views of one of his years, ability and experience. He deplores the condition of affairs in any case wherein the question of invention is decided by the *mere opinion* of the court. "Formed in every case *after the event*, the matter is at once removed from the domain of evidence and is cast upon the sea of uncertainty, where it is subjected to the varying qualities and shifting views of the minds of judges, who, however, while trained in the science of the law, have, as a general rule, no personal experience in the operation of an inventor's mind." He favors the methods of the courts in the earlier decisions, as having been guided

by certain definite rules in determining this important question, while many of the later decisions of the highest court have determined the question upon mere opinion *after the event*. Mr. Renwick cites, Earl *vs.* Sawyer (4 Mason, 1), as containing a rule by which invention may be determined, viz.:

Earl *vs.* Sawyer.—A change was decided to be *new* under the patent law when it had not been known or used before. It was decided to be *useful* if it would accomplish the purpose for which it was designed, and was not noxious or hurtful.

Mr. Renwick says, p. 4: "These *two* requirements of novelty and utility are clearly susceptible of proof by evidence; and it is deducible from the earlier decisions, and those which have followed in the same line, that a change which involves those requirements is an invention within the meaning of the patent law within certain well-defined exceptions." The exceptions which he notes in Section 6 are where the changes are simple and not sufficient to involve invention, such as a *mere change* in size or degree, in proportions, of material, of location or arrangement, the mere application of an old thing to a new purpose, the mere application of an old thing to perform its usual functions with its usual mode of operation or movement, mere substitution of an old device for another, a mere duplication of old devices, a mere change of the direction of movement of a moving device, the discovery of a new property of matter. This is not saying that changes do not involve invention, but that *mere* changes, or such as are so simple as to be within the knowledge of the ordinary skilled mechanic are not invention.

It is hard to say that the rule which Mr. Renwick seems to adopt, or at least suggests as the method of determining what is and what is not patentable invention, is itself an easy rule of guidance, viz.:

Under Earl *vs.* Sawyer, *supra*, invention equals a change not known or used before (it being understood that the change is not a *mere* change of size, proportion, etc., such as noted in the exceptions referred to); and, secondly, the

change must be useful, and is useful if it accomplishes the purpose for which it was designed, and not noxious or hurtful. These two requirements of novelty and utility are stated to be susceptible of proof by evidence.

This rule may be as positive, with the exceptions noted, as it is possible to formulate, but it is certainly not infallible. The exceptions themselves form such a very broad class that one or more of them are apt to enter into the consideration of almost every case where there is any doubt; and again, the exceptions to the exceptions, which are noted on pp. 5 to 40, in the cases therein cited, render the rule still more difficult of application, so that we are unwillingly obliged to agree that Mr. Walker is not far from right when he states, in his work on patents, section 24, before quoted, that the ideal line which separates things invented from things otherwise produced has never been completely defined or described. There is no affirmative rule by which to determine the presence or absence of invention in either case; and with Robinson and others, that what is invention is perhaps incapable of exact definition.

It is true the thing must be *new* and must be *useful* to constitute a patentable invention; the mere fact that it is useful does not make it *new*, but everything that is new, and is sufficiently worth fighting for, to get into the courts, is generally *useful*, and consequently this question of utility does not usually seriously hamper the judges in their decisions.

The main question is: "What is *patentable newness?*" In Earl *vs.* Sawyer (4th Mason, 1) (1825), it was held to involve invention to substitute a circular saw in the place of an upright saw in a shingle machine, the other parts remaining substantially unchanged.

This case was about as short a distance over the *border line* of invention as any case ever passed upon by the Supreme Court of the United States where the validity of the patent was sustained. The patent was issued December 28, 1822, to one Earl for a shingle sawing machine, and the only difference existing between it and the invention of a

prior patent of the same inventor consisted in the substitution of a circular saw for a perpendicular reciprocating saw in the shingle machine. The two machines were the same, with this exception. It was proven that circular saws were in use before in other constructions.

This is one of those cases where the court was influenced somewhat by practical results. It was shown that while the old machine sold for $60 or $70 the new machine sold for $150 or $200.

Judge Story held: "If it is new; if it is useful; if it has not been known or used before, it constitutes an invention within the very terms of the act, and, in my judgment, within the very sense and intendment of the Legislature."

Hotchkiss *vs.* Greenwood. In the case of Hotchkiss *vs.* Greenwood (11 How., 249), the improvement consisted in making knobs of clay, or porcelain, and in fitting them for their application to doors, locks and furniture, having the cavity in the knob in which the shank is inserted, and by which it is fastened, largest at the bottom and in the form of dovetail, or wedge reversed, and secured in the knob by pouring the metal in a fused state. The claim was as follows:

"The manufacturing of knobs, as stated in the foregoing specifications, of potters' clay, or any kind of clay used in pottery, and shaped and finished by moulding, turning, burning and glazing and also of porcelain."

The Supreme Court decided the patent to be invalid; that the mere substitution of porcelain in making knobs for metal, wood, or other material did not involve invention; that the difference was merely formal and destitute of ingenuity. It might have afforded evidence of judgment and skill in the selection and adaptation of the materials in the manufacture of the instrument for the purpose intended, but nothing more.

Mr. Justice Nelson, in delivering the opinion, stated: "I remember having tried an action in the Circuit in the District of Connecticut some years since, brought upon a patent for an improvement in manufacturing buttons. The foundation of the button was wood, and the improvement

consisted in covering the face with tin, and which was bent over the rim so as to be firmly secured to the wood. Holes were perforated in the center by which the button could be fastened to the garment. It was a cheap and useful article for common wear, and in a good deal of demand. On the trial, the defendant produced a button, which had been taken off a coat on which it had been worn before the Revolution, made precisely in the same way, except that the foundation was bone. The case was given up on the part of the plaintiff. Now, the new article was better and cheaper than the old; but I did not then suppose, nor do I now, that this could make any difference unless it was the result of some new contrivance or arrangement in the manufacture. Certainly it could not, for the reason that the materials with which it was made were of a superior quality, or better adapted to the uses to which the article was applied."

The case of Hotchkiss *vs.* Greenwood was not decided without dissent. Mr. Justice Woodbury filed quite an elaborate dissenting opinion, in which he stated, *inter alia:* "Now on the point as to the invention being patentable, the direction virtually was to consider it not so, if an ordinary mechanic could have made or devised it; whereas, in my view, the true test of its being patentable was, if the invention was new, and better and cheaper than what preceded. This test, adopted by the Circuit Court, is one sometimes used to decide whether the invention for which a patent has been obtained is new enough or distinguished enough from the former invention to prevent it from being an infringement, and to justify a new patent for it, and not, as here, whether it is valuable or material enough *per se* to be protected by any patent . . . but it is impossible for an invention to be merely colorable, if, as claimed here, it was better and cheaper; and hence this last criterion should, as requested by the plaintiffs, have been suggested as a guide to the jury. . . . There is a new manufacture, as here, of clay into knobs or knobs with a dovetail hollow combined with a shank. The books are full of such slight changes in structure, composition or mode of application, which were

novel and better in their results and therefore upheld, and were not and could not be regarded as the *mere* application of an old machine to new purposes, besides the new material and the new mode of fastening when the results, as here, are considerably improved, they suffice to make the invention patentable. These are then all required by the strictest law, viz.: "diversity of method" and "diversity of effect" (citing Webster on Subj. Matter, Phillips on Patents, 122.)

This clearly illustrates the diversity of opinion, even among the judges of the Supreme Court of the United States, as to *what does constitute invention.* Applying one of the rules cited, it would come under one of the exceptions noted, and consequently would not involve invention, being a *mere* substitution of material. But right here the difficulty occurs in applying the rule, or exceptions, as to whether the case came within the exceptions and involved a *mere* substitution of material and nothing more. The majority of the court thought that it did, the minority thought it did not, but involved something more.

A different ruling was made in the suit upon the patent issued in September, 1848, and reissued 1861, to John Young, for a washing and wringing machine, having its rolls covered with India rubber. Rolls in like machines had been previously covered with cloth and felt, and Young's machine was the first in which the rolls were covered with rubber. This, it was held, was patentable; that it was *not a mere* substitution of material, as the rubber was impermeable to water and more elastic. All that Young did in this case was to take off the cloth or felt covering from the rolls and fasten on a rubber cover. The qualities of the rubber, which were particularly advantageous in this particular use, were not discovered by Young, but were known before; viz.: that it was elastic and impermeable to water; therefore, he cannot be said to have discovered anything. He undoubtedly made a better machine, but it might also be said, and was admitted, that the Hotchkiss knob made a better knob. The difference between these two cases may be said to reside in the fact that in the Hotchkiss patent the knob of earthenware had no function to perform which the old

wooden knob did not perform, while the rubber in the Young machine had a function to perform which differed from the old rollers, though only in degree.

It is clear when the cases resolve themselves into such fine points that the court has a decided advantage over the patent attorney in that its finding is final and conclusive, while the patent lawyer's finding is merely interlocutory. One excellent test to apply to the question of invention, where a serious doubt exists, is, "does the alleged new thing fulfil useful requirements not previously met or performed, or does it perform any new and useful function in the combination in which it is employed?" Arguing back from this point, if the answer is in the affirmative, careful examination will prove that the difference or change in the new thing, although slight, is material and patentable. In the case of Foote *vs.* Silsby (1 Blatchf., 445), subsequently affirmed in the Supreme Court of the United States, 20 How., 378, the device involved consisted in a stove with its draft valve connected by two levers with two expansion rods of sheet brass; these expansion rods being brass, contracted and expanded to a greater degree than the iron of the stove; by this means the draft valve was closed and opened. Numerous devices operating in a substantially similar manner by the expansion and contraction of the different metals being differently affected by the same degree of heat were shown to have existed long prior to the date of the Foote patent, which was May 26, 1832.

Judge Nelson, in deciding the case in the court below, said, *inter alia:* "The substance of the discovery as claimed by the plaintiff, and secured to him by the patent, is the application of the principle of the contraction and expansion of a metallic rod, by the use of certain mechanical contrivances, particularly described and set forth, to the cast or sheet iron stove in common use, by which means he produces a self-regulating power over the heat of the same at any given degree of heat that may be desired within the capacity of the stove. This is the thing invented. It is, in a word, the application of a well-known principle *to a new and useful purpose;* and the question is, whether or not the

patentee was the first and original inventor, or whether it was before known and in public use. Now, although it is shown (assuming for the present that we may look into the books not in evidence) that the principle had before been applied to the regulation of heat, as in the instance of Dr. Ure's 'Thermostat,' and Bonnemain's 'Heat Regulator,' and some others, yet, from aught that appears from testimony, or from any book that has been produced, the plaintiff was the first person who applied the principle to the *regulation of heat to* stoves; and for this he was entitled to a patent and to be protected in its enjoyment (citing Phillip's Patents, Chapter 7, Sec. 6, p. 101). It is not a new use of the principle as previously applied to the regulation of heat, which would not be patentable; but a new application of it by new mechanical contrivances and apparatus by means of which a new and beneficial result is produced in the use of the article to which it has thus been applied, viz.: the common cast or sheet iron stove."

Mr. Justice Nelson subsequently, in another phase of the same case, 2 Blatchf., 270, held: "Where a party has discovered a *new application* of some property in nature, never before known or in use, by which he has produced a new and useful result, the discovery is the subject of a patent, independently of any peculiar or new arrangement of machinery for the purpose of applying the new property in nature; and hence, the inventor has a right to use any means, old or new, in the application of the new property to produce the new and useful result, to the exclusion of all other means."

The cases selected and presented in considering the question of What is Invention? are those principally in which the spark of invention, if existing at all, was almost invisible. When consulted upon the question of the patentability of an alleged invention wherein the existence, or the possibility of the existence, of the exercise of the inventive faculties is not above suspicion, the attorney's mind frequently turns involuntarily to a tin box tightly closed, containing caustic alkali, and to the process of putting it up.

I refer to certain two reissue patents granted to George Thompson, one for caustic alkali enclosed in a tight metallic integument or metallic casing, and the other for the process of putting it up. The original patent upon which these reissues were granted was issued October 21, 1856.

Suit was brought against infringers at least twice, and at least twice were these patents sustained, and the infringers enjoined. The patents were represented by Mr. George Harding, one of the ablest patent attorneys of this country, and whose name is associated with more important patent suits than that of any lawyer of the century; one whom Philadelphia is justly proud to claim her own.

The validity of the patents was attacked in the case of the Pennsylvania Salt Manufacturing Company *vs.* Thomas (8 Phila. R., 144), as well as in Same *vs.* Guggenheim. In the original patent the invention was stated to consist in a new and useful mode of wrapping cakes of potash or caustic soda in air-tight wrappings, so as to preserve it from the action of the atmosphere, being designed to enable the manufacturer of these caustic alkalies to put them up in original packages of uniform sizes and weight, of such convenient size that when a package is open the whole may be used at once. In one of the modes described the caustic alkali is poured in a molten state into sheet tin boxes cemented at their edges, and while the molten alkali is hot the lid is closely fastened down, so as to exclude the atmosphere.

The late Judge McKennan, in deciding the case in the United States Circuit Court of this district, said, *inter alia:*

"A graver question is that which brings in question the patentability of the alleged invention. A patentable subject must be not only new and useful, but it must involve some exercise of the inventive faculty, and it must not be merely the application of an old thing to a new use. It is undoubtedly true that small metal cans and infusible cement were in use before Thompson's invention, and that caustic alkalies were preserved from deliquescence by inclosure in air-tight packages of glass, iron and wood; but still the fact remained that caustic soda was unavail-

able for general use, and especially for the domestic manufacture of soap. By Thompson's method it was invested with commercial properties and practical adaptabilities which did not pertain to it before. . . . The patentability of an alleged invention is, in many cases, most satisfactorily shown by its *utility*. In Webster, on 'Subject Matter,' 30, it is said: 'The utility, then, of the change, as ascertained by the consequences, is the real practical test of the sufficiency of an invention; and since one cannot exist without the other the existence of one may be presumed in proof of the existence of the other.' . . . Judged by the standard of utility, then, a sufficiency of invention to support this patent is to be presumed."

It will be clearly seen from this brief consideration of the question, What is patentable invention? that it is by no means easy of definition, and the difficulty of establishing a positive rule applicable to all cases will be fully appreciated.

ENGINEERING PRACTICE AND EDUCATION.

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[*Continued from p. 366.*]

We will next consider the subject of drawing. That this is an absolute necessity to the engineer I think no one will deny.

Drawing, to a great extent, is his language. It is the method by which he expresses a large class of his ideas. Go into any extensive shop or manufactory where they make a business of manufacturing machinery or of building structures, and you will find that all operations are controlled through the draughting room. Drawings must be made of every piece that is to be manufactured, and of every machine or structure that is to be erected, and either

the drawings themselves, or tracings made from them, or blue prints taken from the tracings, are sent into the shop, and these form the instructions of the workman how to make the pieces. In many establishments, it is the chief draughtsman who has charge of designing the machines and structures, so that when this is the case the chief draughtsman becomes practically the engineer of the establishment.

Moreover, neatness and accuracy must prevail in the drawings, so that they can be easily understood, for a mistake made by the draughtsman on a drawing, or a misunderstanding of the drawing by the workman, if not discovered in time, may result in a large pecuniary loss to the manufacturer.

Freehand drawing and lettering are both very important matters, *i. e.*, freehand drawing is needed to such an extent as will enable the young man to sketch easily and readily any part of a machine or structure, and to do this work with sufficient speed and clearness to be able to complete it while he has access to the machine, so that he can subsequently make a complete set of working drawings from his sketches, a thing which is often necessary when a draughtsman is sent outside for information. Neat lettering and dimensioning add very materially to the clearness of a drawing, and hence render it less likely to be misunderstood; and this is especially necessary since the workman should always be instructed to make use of the figured dimensions, and should never be allowed to scale a drawing.

Graphical methods are sometimes employed for the making of calculations necessary in the designs of machines or structures, and when these are used, of course, great accuracy is an absolute necessity in making the drawing. Seeing now that drawing plays so large a part in any engineering work, let us consider how it should be taught, and how the course should be laid out.

We may say that there are two objects to be accomplished, the first being the execution, and the second the power to express ideas by means of drawing, and to read the ideas of others, which have been expressed by the same

means; in other words, to be able to produce, from the piece itself, the necessary working drawings, and *vice versa*, when, having the working drawings, to be able to understand how the machine is made in all its details.

A certain amount of time will have to be employed at the outset to teach the use of instruments and to enable the student to perform the actual work of drawing, observing, of course, accuracy and neatness. But as soon as this necessary preliminary training in execution is accomplished, so that the pupil begins to do his work with a fair degree of accuracy and neatness, then the attempt should be made at once to have him acquire the language, so that he can readily translate ideas into drawing, and *vice versa*. Now, the mathematical basis of drawing is descriptive geometry, hence the student should be set at once to study descriptive geometry, being made to work out and demonstrate the propositions on the blackboard, as in any other mathematical class-room exercise; and he should be made to take a broad view of the subject so that he will understand the drawing, whatever be the angle, whether first, second, third or fourth, in which it is made, or if it is partly in one and partly in another. I do not believe in the method that confines him to the first angle for a long time, until he gets so used to that particular angle that the moment a figure is placed in any other it looks difficult to him. Indeed, in practice all angles are used, but if one is employed more than others it is the third and not the first. But the student has only obtained a firm grasp on the subject when he is equally at home and familiar with the figure in whatever angle it is placed.

Then, parallel with the class-room work, where he is taught the theory, or, in other words, descriptive geometry, he should be obliged to make correct and accurate drawings, giving the constructions for a certain number of the problems of descriptive geometry. The only difficulty in the matter will be found at the very beginning in making the student exercise his imagination sufficiently to grasp the central idea of projections in any of the angles. In this he must be thoroughly drilled; the rest is then easy. I

might add that here also the teacher should have in view in laying out the propositions to be studied by the class, the needs of an engineering course; and while they should be comprehensive, and cover all the main principles, they should be chosen from the point of view of engineering and not from a desire to keep as nearly as may be to the course which was originally given by Monge, the father of descriptive geometry.

Now, when our student is familiar with descriptive geometry, and has made reasonable progress in execution, and understands how to express ideas on paper, at least as far as descriptive geometry goes, the next step to take is to cause him to make working drawings from measurements made by himself of pieces of machinery, or of structures; thus teaching him how to determine what views of a piece it is necessary to make, how to arrange the drawings on paper and how to dimension them.

However, at the outset, we are confronted with the fact that every different works has its own system of making drawings, differing from one another in some minor details, usually in the manner of putting on dimensions and sometimes in the manner of putting on shade lines, or some other minor things; *i. e.*, things about which it is of minor importance which system is followed, but where it is of the very greatest importance that some one consistent system should be employed.

Now, some one good system ought to be chosen, and the student should be made to adhere to it. Also such, conventions and rules as are universally adopted should be taught him, such for example, as that the diameter and not the radius of a piece that is to be made in a shop should always be designated; that the over-all dimensions of pieces should always be given, etc.

After the student has done a reasonable amount of this kind of drawing, which might be called drawing from models, he should next be required to make the detail drawings for the separate pieces of some machine, and having done this, should make the assembly drawings from these detail drawings, thus learning how the separate pieces are

to be put together to form the complete machine, to detect errors in the detail drawings, and how all this is to be represented on paper. Such a course of instruction is necessary in order to give the student the training needed to enable him to carry out the reverse process, which is the course he will most frequently have to follow in the draughting-room of the works.

For drawing, pure and simple, such a course as that outlined will probably give a reasonable skill in executing and in making and reading drawings. Of course, however, there ought to be, if possible for all, and without fail for those who are aiming towards topographical work, a reasonable amount of drill in topographical drawing; then for all there should be, as I have said, instruction in freehand drawing, and also in plain lettering.

As to the drawing done in connection with the other work of the students, which would naturally form a very considerable portion of their total drawing, I shall not speak here, for it belongs in connection with the other work; the students are supposed to have acquired the language of drawing and to use it whenever needed.

Perhaps I ought to mention, also, that all engineering students should be taught to make blue prints, an easy matter as far as teaching it to the student goes, but one of the greatest importance in practice.

It is almost impossible to understand to-day how we ever could get along in our large shops and manufactories of machinery and of structures without the use of blue prints. In former times drawings had to be made, of course, of all the parts of the machine, and then tracings of each part to send to the shop for the use of the workmen. These tracings were often spoiled in the shop, and more had to be made, involving a large amount of labor; also, if the purchaser of the machine wished a tracing, one had to be made for him. As things are now, the original drawings are generally made in pencil, these being seldom inked. Then one tracing is made, and from this are taken as many blue prints as are desired. If one is lost or spoiled, it can be replaced with very slight labor and at small expense.

Next comes mechanism, which may be said to be the most elementary of the subjects that are commonly considered to constitute the strictly professional work of a mechanical engineer. It deals with the combination of the motions by means of which each machine is enabled to accomplish its own special functions when the power has been furnished to it.

Were I to undertake to give a list of cases where the invention of certain special mechanisms have revolutionized certain industries, or have advanced enormously the industrial progress of the world, or caused a great saving of labor, and brought about incalculable benefits for mankind, my task would be almost endless.

The invention of different combinations, and, hence, the introduction of machinery of different kinds, by means of which the industrial progress of the world has been rendered possible, began in the very earliest ages, long before the advent of steam, and even back in the days when the only sources of power were the work of men and of animals. Indeed, had it not been for machinery the industrial progress, and, hence, the civilization of the world would have been impossibilities. There would have been no commerce, and no occasion for roads or means of communication, for the world would have remained in a savage state. Consider what was the condition of the textile industries even just before the time when Hargreaves invented the spinning jenny, and Arkwright the spinning frame, and Crompton the mule, compared with their condition to-day, and you have an example, in one department, of what machinery has rendered possible, and of how incalculable are the benefits that it has conferred on mankind. Then they had only the hand-spinning wheel, and the amount of work that could be accomplished was very small. The inventions of Hargreaves, of Arkwright and of Crompton were merely combinations of mechanism, and, although they still used manual labor or horse-power, the amount of yarn that one person could produce was many times what could be accomplished by the same person with the hand-wheel. To-day we should look upon these machines of Hargreaves, Ark-

wright and Crompton as exceedingly crude, and instead there has been developed all the wonderful variety of marvellous machinery that hums in the different textile manufactories of the world, furnishing us with all the delicate and rich fabrics with which we adorn our persons and our houses at the present day, our cotton goods, our woollens and worsteds, our silks and satins and laces, our carpets and our tapestries, etc.

Coming down to a later date, consider the enormous saving of labor, and the enormous increase in the product of the labor of one individual, by the introduction of the sewing machine, even leaving out of account the fact of driving it by water or steam power. Consider how very general is its use, that one can hardly enter a private house that is without one, to say nothing of the enormous number used in manufactories of clothing and of other articles which are made by sewing.

Furthermore, it has found its way, with some modifications into the manufacture of shoes; and in this industry we find a great number of special machines in use which are simply combinations of mechanism designed to accomplish certain special results.

Then consider the tools used in our machine shops, and places where machinery is manufactured; the lathes, the planers, the drills, the shapers, the milling and the grinding machines, the gear cutters, and the host of special machines in constant use all over the world.

Consider the bolt and nut machines, the machines for making barbed wire, the nail machines, the screw machines, and a host of others too numerous to mention. To call them labor-saving devices is a misnomer, for they rather render possible the work of the world, such as it is at the present day, which would be an utter impossibility without their aid.

The methods of combining the different parts of a machine, so as to obtain the desired motions, have been reduced to a system, and this system constitutes the study of mechanism.

It aims to make the student familiar with the methods

by which such results are to be accomplished, and to teach him the principles governing them, so that he may undertake intelligently the devising of new arrangements, and may avoid making or proposing absurd, impossible or unadvisable combinations. It depends mainly on pure mathematics and involves a knowledge of drawing. The mathematics principally needed are algebra, geometry, trigonometry and descriptive geometry, while it is very useful and will often save work and enable one to reach results more easily to have a knowledge of analytical geometry and calculus.

Drawing is, of course, indispensable also. We might well say that mechanism is a mathematical subject, and teaching it requires the use of the class-room and the drawing-room. To a certain extent it is desirable and almost necessary to use models also, but care should be taken that the student fully understands a drawing; for if, in order to work out a combination, he finds it necessary to build or look at a model before he can predict with certainty what it will accomplish, he has not properly learned his mechanism. In order to have a knowledge of the subject that is sufficient to enable him to make real use of it in practice, he must be able to put his ideas into shape in a drawing readily and quickly, and to predict the mode of action from this drawing and such mathematical calculations as he may make. If, on the other hand, a drawing is presented to him, he should understand how the machinery represented will behave, and what can be expected of it. Moreover, he should be able to do this with mechanism of very considerable complexity, for he will often meet with such machinery in the course of his practice.

Now, after he has had his systematic study of mechanism, it seems to me that it is of great importance that he should make a study of the usual machine tools that are in general use to-day, such as lathes, planers, milling machines, etc., studying first the characteristics of the usual mechanisms they contain, noticing the reasons for choosing some and not others; as, for instance, the questions of stiffness, of wear of the surfaces, of stability, etc. Of course, he should

have an opportunity for studying some forms of these by personally inspecting them in the shops attached to the institution, but these are necessarily limited in size, and there is also an enormous variety of other combinations in common use for different purposes. This work can best be accomplished by the teacher, probably, if he puts in the hands of the students a large and systematically selected collection of cuts of the machines in general use made by some of the best makers. The teacher, of course, must be familiar with these machines, and he must be able to explain to the class their general as well as special features, and see that the student becomes familiar with them. A little instruction of this sort will be of great service to the student in many ways, both in his course and in his subsequent work in the practice of his profession.

Another thing that, in my opinion, is very desirable to do by way of making the student's study of mechanism serviceable to him, I will now explain.

In the study of machine tools just referred to, the student gains a familiarity with the characteristics of those kinds of machinery which he will meet with at every turn; but, as a rule, the ordinary machine tools cannot be said to involve a very large amount of complicated mechanism; hence, something should be done by way of making him thoroughly familiar with certain classes of machines that, in order to accomplish their objects require a large amount of very complicated mechanism. Hence, he should be taught the construction of some such machines in all their details, and then, if possible, he should find in the laboratory examples of some of these machines, and be made to understand them in detail—as it were, to dissect them, to see for himself that they do accomplish what is claimed for them, and to verify, by his own computations from the dimensions of the parts, whether the actual motions are such as agree with his calculations; and if not, to find out why they are not, or, in other words, wherein he made his mistakes in calculation. Now, it matters comparatively little what kinds of machines these are, provided only that some of them, at least, involve a very considerable complication. In the case

of our own classes, we have a lot of textile machinery, the most complicated of which is a spinning mule; and the students are required to become thoroughly familiar with the action of all the parts of these machines. For example, in the case of the mule, they must understand thoroughly what is the mechanism for carrying out and returning the carriage, and how this is caused to vary its speed at different times; what is the mechanism that does the twisting; what the winding; how the roving is drawn out in the beginning, etc. By having such a machine in the laboratory the student can be made to study and understand it; whereas, in a mill the mules could not be stopped and run at his convenience and for his benefit. Moreover, after the student has had a good course in mechanism, and has then had to render himself familiar with all the parts of a machine as complicated as a mule, he is better prepared to grasp and understand complicated mechanism of any kind; as, for instance, a barbed wire machine, a bolt and nut machine, an automatic screw machine, etc.

Then, again, there is a special class of problems in mechanism, which concern machines that generate power, as the mechanism of the steam engine; but the one portion of the mechanism of the steam engine that requires special attention is the valve gear. Hence, the student should have such thorough instruction in valve gears and link motions as shall drill him in the mathematical principles for working out valve gears in all their details, and should also be taught the different ways of designing and making those in use to-day, the ways of constructing them and their adjustments, all this being really a part of the mechanism course.

Now, although I have already met and answered a question that might arise in the minds of some, it will, perhaps, be worth while at this point to raise and answer it again. It is this: Is it as important for the young man who expects to devote himself to what is commonly called civil engineering to be thoroughly drilled in mechanism as it is for the mechanical engineer? and I answer very decidedly, yes. The civil engineer who is to build bridges or engage

in some of the kinds of engineering which I enumerated under my list of so-called public works, cannot carry on any work of any magnitude without having to use a good deal of machinery, and is liable to have to use special machinery; and the more important the work on which he is engaged the greater the use he has for machinery of all kinds; and if the development that has taken place up to the present time is any sign of what is to take place in the future, he will be more and more intimately concerned with the use of machinery, which he will need to direct, to set up, and perhaps even to design.

Another matter to which it may be well to refer is that a thorough knowledge of the principles of mechanism will tend to guard the prospective engineer against the danger of inventing absurd and impossible combinations of mechanism and impracticable machines, or to expect to accomplish by means of mechanism only results that cannot be accomplished by it alone.

Indeed, were I to attempt to give you a list of all the worthless and absurd inventions of the world, I should probably find that the greatest part of them consisted of some form of mechanism. The very fact that the invention of certain machines, *i. e.*, of the mechanism of those machines, has had such a powerful influence on the welfare of mankind is, of itself, an invitation to a great many people who are ignorant of scientific principles, and also of the requirements of machinery, to try their hands at inventing, and the patent offices of the world contain an enormous number of such worthless contrivances.

The next course of which I shall speak is one which vitally concerns the engineer at every turn, and, therefore, one in which it is absolutely necessary that he should be very thoroughly drilled. The course to which I refer is theoretical and applied mechanics. This term has been used in different senses at different times, and in different places, but the sense in which I shall use it is that which is now most generally accepted; *i. e.*, it includes a general and mathematical discussion of the action of forces upon bodies at rest or in motion, and also a full treatment of the strength

and elasticity of the materials used in construction, both from a mathematical and also from an experimental point of view. To speak more in detail, it includes a treatment of such subjects as the following, viz.: composition and resolution of forces, conditions of equilibrium, determination of the centers of gravity, of lines, areas and of solid bodies; the general laws of dynamics, as a treatment of uniform and varying motion; the pendulum, determination of moments of inertia, and of centers of percussion, etc.; the laws of friction; determination of the work used up in friction, both by mathematical calculation and by actual experiment. Then come the determinations of the stresses in the different members of trusses of all sorts; and then a study of the mathematical discussion of the theories of the strength and elasticity of materials, *i. e.*, study of the distribution of the stresses acting in tension rods, struts or compression pieces, beams or other pieces bearing a transverse load; also in all sorts of pieces that are subjected to shearing, including, of course, riveted joints, shafting and beams, as well as in other pieces; the distribution of the stresses acting in a hook, or in any tension or compression piece that has to bear an eccentric load; the determination of the greatest intensity of the stress, or, in other words, of the stress acting on the most strained fibre in each case; also the determination of the strains (elongations in the case of tension, and shortenings in the case of compression pieces) that occur in all the different parts of the piece; the modes of determining the deflections of beams, the angle of twist of shafts, or the amount of yielding of pieces generally, under load; theories and modes of calculation of the stresses at different parts of continuous girders, *i. e.*, beams which are continuous over more than two points of support; also of the deflections of, and the shearing stresses of, such beams; determinations of the stability of, and of the stresses acting in, arches which bear a load, whether they are of stone or iron; theory of the stability of domes, and then a study of the theory of elasticity.

Turning to the experimental side, the student should be familiarized with what experiments have been made

upon and what results they have shown as regards the strength and the stiffness of such pieces as are used in construction to bear a load. Moreover, the account of these experiments should be brought up to date, and special emphasis laid on the results of those where the conditions of practice, as to size, manner of loading and treatment generally, have been exactly, or at least approximately, copied. The student should be made to study carefully the results that have been obtained in these experiments, to collate and compare, and to draw from them such conclusions as are warranted, to see how far and in what ways they may modify the ordinary mathematical calculations and the ordinary ideas in regard to the action of such pieces in bearing loads. To study the effects of the repetition of stresses to which pieces are very frequently subjected in practice; in short, to put himself as nearly as possible in such a condition that he knows what is the extent of our knowledge of the facts as shown by experiment in regard to the behavior of the materials of construction, wood, iron, steel, stone, cement, concrete, etc., when subjected to such loads as they have to bear in practice.

It would seem almost unnecessary to say that such subjects as the above are of the most vital importance to the engineer, and yet, absurd as it may seem, there have been those, and there are still occasionally some, who consider such information as of no consequence. These are the men who believe in doing their work by rule of thumb; and they would proportion the parts of any machinery or structure which they might have to build by one of two methods, either of which they would call practical, for the reason only that it lacks the element of scientific knowledge. The first method is, if the thing to be designed is similar to something that they are familiar with, to copy that—whether it is right or wrong, whether it is far stronger than need be, or on the verge of collapse—simply because they are following a precedent; if it is to be of the same sort as something that has gone before, but is to be of greater or less capacity, they are very liable to determine the sizes of the new one from those of the old one by

the rule of three; or, if the new machine or structure is wholly unlike anything they have seen before, or if, though like something they have seen before, they decide not to copy the old, they determine what dimensions to give it by guessing, and call their guesses practical experience, notwithstanding the fact that they are often very poor guesses.

The second, and more usual method which such men are liable to follow, is to determine the dimensions of the pieces by means of formulæ found in some handbook, and they assume that because a formula is found in a handbook, or rather in the handbook which they have adopted as authority, therefore, it must be right, trusting blindly to the correctness of the formula and constants given in these handbooks, although they have no knowledge of the assumptions made in the deduction of the formulæ, nor of the experimental basis upon which the determination of the constants rests.

It is needless to say that either of these methods is liable to, and often does, result in disaster, and accident after accident has resulted from, and lives have been lost in consequence of, the use of each of such methods as these.

The consequences of structural weakness in any member of a structure or machine are:

(1) Lack of the necessary stiffness, and hence, in the case of a machine, the turning out of poor work; or, in the case of a structure, oscillations which render it unsuitable for the performance of fine and accurate work of any kind.

(2) Breakage of the structure or machine.

(3) Injury to surrounding objects, personal injury, and perhaps loss of life.

Hence it is very important to provide the requisite strength and stiffness in all the members of the structure or machine. Increase of the amount of material does not necessarily mean increase of strength.

The first step towards determining the proper dimensions for any piece, in order to secure the requisite strength and stiffness, is to know the forces acting upon it, and how they act.

Then we need to determine the stresses to which the piece is subjected, in consequence of the action of these forces, and also the strains, *i. e.*, the elongations, compressions, deflections or deformations due to these stresses.

Next, whether the forces are quiescent, or whether they are oft-repeated, and what are the conditions of the repetitions.

Then we are ready to determine what dimensions we must adopt in order that the greatest stresses at any point shall not exceed an amount consistent with safety, this amount being determined by experiments made upon the strength of the material, and so that the greatest strain shall not exceed an amount consistent with safety and with the proper stiffness of the machine or structure.

If, for instance, we are to decide upon the proper dimensions to adopt for the different pieces that compose a machine, we need to ascertain, first, what is the greatest force exerted at that end of the train of mechanism where the work is done. It becomes then merely a question of composition and resolution of forces to determine the forces acting on any one piece of the machine. We shall thus find, in general, that some pieces are subjected to direct tension, some to direct compression, some to a transverse load, some to torsion, some to a combination of different stresses, and some to various eccentric loads.

Suppose, now, that we have a structure, for instance a building. We must first ascertain the greatest loads that can come upon any part of the floors, and then determine the stresses produced in the beams, columns, walls, etc., by these loads. But we must also observe that the greatest stresses are not necessarily those produced by the greatest loads, and hence we must determine the loads which produce the greatest stress in each member. Similar remarks apply to a bridge structure.

A few examples will serve as illustrations. Take the case of one of the columns of a building. When the greatest load per square foot covers the entire floor above, the resultant of this load on that floor acts along the center line of the column, and the stress per square inch due to this

load is uniformly distributed over the section. When, on the other hand, the floor on one side is fully loaded, and the floor on the other side is not loaded, then the total load is less than in the other case, but its resultant does not act along the center line of the column, but is eccentric. Now, it is plain that the eccentricity of the load introduces a tendency to bend, and, under such conditions the load that will break the column is very much less than it would be when the load resultant is central.

Now, when a column in a building is to be calculated, we should determine what is the greatest stress on one side, due to having as great an eccentricity of load as is possible to be attained in the use of the building, and we should see to it that the dimensions of the column are such that this greatest stress shall not exceed safe limits. Further, if with most of the sizes of columns used in buildings we were to determine the amount of this eccentricity, and also the probable amount of the deflection under any central load that the column would have to carry while in use in the building, we should find that the latter is almost inappreciable compared with the former, and yet it is not at all common for people to-day to compute the stresses due to the eccentric loading, and instead they often use some formula which was devised for central loading, and which was deduced by making certain assumptions in regard to the deflections which experiments on actual full-sized columns do not bear out.

This I call neglecting the important consideration and performing a great deal of computation on a very minor one, by means of a formula that cannot be proved, but which is given in the handbooks. Is it any wonder that columns sometimes fail?

Another illustration is to be found in connection with the calculation of fly-wheels of steam engines. Every once in a while we hear of the bursting of a fly-wheel, the fragments of which have, in consequence of the breakage, been hurled like so many projectiles, in all directions, carrying death and destruction in their paths.

Now, in several cases of wheels which I have examined,

the stresses existing in the bolts which unite the separate sections of the rim, and the stresses in the portions of the rim near the joints, were decidedly greater than a due regard for safety would allow, and greater than the designers of the wheels would have allowed had they been designing some other construction, or had they realized their existence in the case of the wheel. The difficulty in these cases, apparently, was that the designer, if he figured at all, disregarded the fact that the bolts were not placed in the line of direction of the resultant of the tension in the rim, but were located on one side of that line, and that therefore they had an eccentric load, and, having neglected to figure the extra stress due to the eccentricity of the load, he did not provide sufficient strength in the wheel to resist it.

Another way in which erroneous results may have been reached is in the misapplication of a rule given in Rankine's books, which applies only when the load is not eccentric.

Another case where disaster occurred in consequence of neglect to consider the effect of an eccentric load (well known to a Boston audience), is afforded by the Bussey Bridge accident, which occurred a few years ago, where, as will be remembered, one of the hangers had a very eccentric pull, while it was only strong enough to bear the load if it had been central. This disaster was the cause, not only of a serious destruction of property, but also of a large loss of life.

Let us turn next from a consideration of the formulæ to the question of the proper constants to use.

If the dimensions proposed for any piece are such that the greatest stresses and the greatest strains in the piece are no greater than the safe allowable stresses and the safe allowable strains, respectively, for that kind of material, then the dimensions chosen are such as are consistent with safety; but if they are larger, the dimensions must be altered so as to bring these greatest stresses and strains within safe limits.

The knowledge of what are safe limits is, of course, an important matter, and can only be determined by experiment.

This principle has, of course, been generally acknowledged for a long time by those who believe, as they should, in calculating the stresses that actually exist, and a great many experiments have been made, and the results of such experiments have been published, and are quoted in books, and, of course, in the handbooks. Now, there are many who accept, as necessarily correct, the constants given in their favorite handbook, without stopping to ascertain under what conditions the experiments were made, and whether or not these conditions are similar to those which exist in the cases they themselves have in hand. The result of such a course is the frequent use of values for allowable stresses which are not suitable to use at all, or which, while suitable in some other case, are not suitable to use in his own case. To make this matter plain, let us use a few illustrations:

In the different handbooks are given various rules and constants from which to determine the breaking loads of wooden columns. Taking the condition of the handbooks a few years ago, the engineer would have found, if he chose to hunt up the records of the experiments upon which most of these constants were based, that their only basis was seven experiments selected out of seventeen, which were made about the year 1840, upon seventeen columns cut out of one good plank of Dantzic oak, which had been cut up and seasoned about one year, the largest piece tested being about two inches square and five feet long; and that since the results obtained from the seventeen did not run very uniformly, ten were thrown aside, and the other seven were used to furnish the constants for the formulæ; and further, that most of the formulæ given in the handbooks took their constants from these experiments, and applied them indiscriminately to wooden columns of all kinds of wood. Moreover, while a few other formulæ were given at that time, they all derived their constants from experiments on small specimens, and made under conditions which rendered them unsuitable to use in actual practice; *i. e.*, the breaking strengths as figured by means of these formulæ and constants were very different from the actual breaking strengths.

Now that experiments on full-size columns of wood have

been made, it is found that different kinds of wood differ very considerably in their crushing strengths; that oak, in regard to which the prejudice has almost always existed that it is stronger than yellow pine, is really not as strong as the yellow pine; and that all the figures that are suitable to use for the crushing strength of timber columns of practical size are very decidedly lower than those given by the results obtained by the Dantzic oak experiments already referred to.

When we stop to consider the reasons for these facts, they become evident, viz.: There exist in timber columns of the sizes and proportions used in practice, knots, season cracks, defects and a lack of homogeneity which do not exist in small selected pieces. Hence, since modern experiments made under the conditions of practice have shown us what are really the values suitable to use in computing the breaking strengths of timber columns, it follows that these old constants were entirely inapplicable.

As a matter of fact, a very considerable number of the handbooks and other books now give the new instead of the old constants; but other authors, either through obstinacy or inertia, have not changed their books to keep up with the times in this respect.

In the case of timber beams bearing a transverse load, the number of experiments made on small pieces, about two inches square and five feet long, is very large; and the constants almost universally given in the handbooks until a very recent date were based upon experiments of this kind. The results, however, differed a good deal among themselves, as they were obtained from different sets, but all are decidedly larger than those that have been obtained from modern experiments made on beams of such sizes as are used in practice, and for the same reasons that were explained in the case of timber columns.

The condition of things to-day, therefore, is that some of the handbooks still adhere to the old constants, differing, however, among themselves, and that others have brought their books up to the times in this regard, and give the new constants derived from the modern experiments, although

not all the handbooks that give reliable constants for columns do the same for beams, nor do all those which give reliable constants for beams do the same for columns.

Until within the past five or six years, the building laws of the city of Boston prescribed that in the case of timber columns and timber beams the safe load to apply should be considered as one-third of the breaking load, the breaking load being calculated from such constants as are given by any good authority. The law did not prescribe any method of determining what is good authority, and hence left it to be tacitly assumed that any of the handbooks, or books of that character, which were used by reputable engineers or architects, might be considered as good authority. In accordance with these directions, what a man would call the breaking load of a given yellow pine beam would depend upon which handbook he happened to get his constants from.

Let us suppose that he took as his authority Hatfield's experiments on yellow pine beams, about 2 inches square and 5 feet long, and used the average of his results. In this case, he would find for extreme fibre stress, when the beam was just on the point of breaking, 15,000 pounds per square inch. Applying to this the factor of safety 3, as required by law, he would find the safe load by allowing an extreme fibre stress of 5,000 pounds per square inch, whereas modern experiment shows that, for beams of practical size, it is liable to be on the verge of breaking when the extreme fibre stress reaches 5,000 pounds per square inch.

Indeed, it is only within the last twenty years that much activity has been displayed in testing the strength of pieces of practical size, and that a flood of light has been thrown on the question as to what are not reliable constants to use in practice. In the case of most of the constants given for iron and steel, the greater part of them have generally been nearer to the truth than in the case of timber, but there has been a very considerable lack of accurate information on the subject.

[*To be concluded.*]

BOOK NOTICES.

Transition Curves.—A field-book for engineers, containing rules and tables for laying out transition curves. By Walter G. Fox, C.E., New York: D. Van Nostrand Company. 1893. Van Nostrand's Science Series, No. 110. 80 pages. 50 cents.

The author here submits six tables, each representing a different transition curve. These curves differ from one another in the rate at which the curvature increases with the number of chords laid off. The tables give the co-ordinates for locating the points at the ends of the chords, as well as the deflection angles, in order that the curve may be run by offsets, if desired. The usual tables of radii and apex distances are also given. T.

Encyclopédie scientifique des Aide-Mémoire. Dirigée par M. Léauté, Membre de l'Institut. Librarie Gauthier-Villars et fils. Quai des Grand-Augustins, 55. Price, per volume, 2·50 francs, unbound; 3 francs, bound.

Since our last notice of this capital technological series, the following additional volumes have appeared:

Hennebert. Lieutenant-Colonel du Génie, ancien Élève de l'École Polytechnique. *Fortification.*

Sorel, E. Ancien ingenieur des manufactures de l'État. *La rectification de l'alcool.*

Alheilig. Ingénieur de la Marine. *Résistance et construction des pièces des Machines.*

Billy, E. de. Ingénieur au Corps des Mines. *Fabrication de la Fonte.*

Minel, P. Ingénieur des Constructions navales. *Électricité appliquée à la marine.*

Minel, P. Ingénieur des Constructions navales. *Régularisation des moteurs des machines électriques.*

Dwelshauvers-Dery. Ingénieur, Professeur à l'Université de Liège. *Étude expérimentale dynamique de la machine à vapeur.*

Marchena, R. de. Ingénieur des Arts et Manufactures. *Machines frigorifiques à gaz liquéfiables.*

Marchena, R. de. Ingénieur des Arts et Manufactures. *Machines frigorifiques à air.*

W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, November 21, 1894.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 21, 1894.

MR. H. R. HEYL, in the chair.

Present, seventy-six members and four visitors.

Additions to membership since last report, twelve.

Mr. John C. Trautwine, Jr., described, with the aid of lantern projections, the subway which is about to be constructed jointly by the City of Philadelphia and the Philadelphia and Reading Railroad Company, and which has for its principal object the abolition of the numerous grade crossings of the Reading Company's tracks which now exist on Pennsylvania Avenue, between Broad Street and the entrance to the Park at Fairmount Avenue.

The dominant feature of the plan is the depression of the railway below the street level, from a point east of Broad Street westward to Twenty-sixth Street, whence the tracks will rise to the present surface level at Thirtieth Street.

From Broad Street westward to Twenty-first and Hamilton Streets, the railroad will occupy an open subway, over which the several north and south streets will be carried upon iron bridges, while from Twenty-first Street northwestward to Twenty-sixth Street it will be in a tunnel, which is to be surmounted by a boulevard.

The operations now under way are confined to the construction of the two elaborate systems of low-level sewers necessitated by the plan. These empty into the Schuylkill River at the foot of Powelton Avenue, whence they extend, respectively, eastward along Callowhill Street to Thirteenth Street, and northwestward along Pennsylvania Avenue to Thirtieth Street. Their maximum depths below the street surface are, respectively, about forty and fifty feet.

Mr. J. L. Gill, Jr., gave a description of the remarkable explosion of a battery of steam boilers, which occurred in October last at a colliery near Shamokin, Pa. The speaker illustrated his remarks by the exhibition of a number of projections of photographs taken on the scene a few days after the disaster had occurred. The subject was freely discussed.

Mr. W. N. Jennings exhibited a series of pictures of the launch of the ocean liner, *St. Louis*, from the Cramps' shipyard, which took place on November 5th.

The Secretary's report included a reference to the several projects for bridging the Hudson River at New York. A view, showing a plan of cantilever bridge of 2,100 feet span, and a suspension structure of 3,100 feet span, was exhibited, and estimates of the cost and other details were stated.

Adjourned.

WM. H. WAHL, *Secretary*.

PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

T. F. TOWNSEND, WEATHER BUREAU, OBSERVER IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR OCTOBER, 1894.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 31, 1894.

GENERAL REVIEW.

The average temperature for October, 1894, 53°.6, is 4°.0 above the average [49°.6] for the past six years.

The highest recorded temperatures occurred on the 1st, 2d, 3d, 19th, 20th and 21st, and were as follows: Lock Haven, 88°; Chambersburg, 84°; Coatesville, 83°; Carlisle, 83°, and York, 83°.

The lowest were on the 12th, 15th, 16th, 18th, and 19th. Shingle House, 24°; Wellsboro, 24°; Saegerstown, 25°; Dyberry, 25°; Hollidaysburg, 26° Smethport, 26°; Selins Grove, 26°, and Somerset, 26°.

From January 1, 1894, to October 31, 1894, the accumulated excess in daily mean temperature at Philadelphia was 521°; at Erie, 762°, and at Pittsburg, 673°.

For the same period the deficiency in precipitation at Philadelphia was 1.57; Erie, 4.17, and Pittsburgh, 8.83.

TEMPERATURE.

	Mean Temperature.	*Mean Precipitation, Inches.*
October, 1888, ...	46°.1	4.03
1889, ...	47°.3	3.85
1890, ...	50°.9	5.87
1891, ...	50°.4	3.06
1892, ...	50°.5	0.78
1893, ...	52°.8	3.26
1894, ...	53°.6	4.26

The means of the daily maximum and minimum temperatures, 63°·4 and 43°·8, respectively, give a monthly mean of 53°·6, which is 0°·8 above the corresponding month of 1893.

The average daily range was 19°·6.

Highest monthly mean, 57°·6 at Philadelphia [Centennial Avenue].

Lowest monthly mean, 48°·3 at Wellsboro.

Highest temperature recorded during the month, 88° on the 1st at Lock Haven.

Lowest temperature, 24° on the 18th and 19th at Shingle House, and on the 15th at Wellsboro.

Greatest local monthly range, 58° at Somerset.

Least local monthly range, 37° at Easton.

Greatest daily range, 56° at Shingle House.

PRECIPITATION.

The average precipitation for the State, for the month, 4·26 inches, is 0·78 inches more than the average [3·48] for the last six years.

General rains occurred on the 4th, 5th, 10th, 13th, 24th, 25th, and 31st.

Excessive rains occurred at 11 stations on the 10th. Cassandria reported 3·0 inches of snowfall, and Grampian 1·0 inch. Several stations reported a trace.

The largest monthly totals of rainfall were: Girardville, 7·66; Seisholtzville, 7·48; Mauch Chunk, 7·06; South Eaton, 6·50; Blooming Grove, 6·42, and Reading, 6·40.

The least were: Greenville, 0·65; Lock No. 4, 1·36; Beaver Dam, 1·65; Pittsburg, 1·72; Altoona, 1·77, and West Newton, 1·82.

WIND AND WEATHER.

The prevailing wind was from the West.

Average number: rainy days, 9; clear days, 12; fair days, 8; cloudy days, 11.

BAROMETER.

The mean pressure for the month, 30·00, is about ·07 below the normal. At the United States Weather Bureau Stations, the highest observed was 30·38 at Harrisburg on the 12th, and the lowest 29·13 at Philadelphia on the 10th.

MISCELLANEOUS PHENOMENA.

Thunder Storms.—Hollidaysburg, 13th; Cassandria, 13th; Johnstown, 13th; Emporium, 13th, 24th; Mauch Chunk, 4th; State College, 24th; West Chester, 4th; Coatesville, 31st; Kennett Square, 31st; Lock Haven, 4th, 24th; Carlisle, 3d, 4th, 13th; Harrisburg, 3d; Uniontown, 22d; Easton, 3d; Blooming Grove, 3d; Shingle House, 23d; Somerset, 24th; Dyberry, 3d; Hamlinton, 3d; York, 24th; Lebanon, 3d; Phœnixville, 31st; Lewisburg, 3d, 4th, 13th.

Hail.—Cassandria, 13th; Johnstown, 14th; Emporium, 13th; Grampian, 13th; Lock Haven, 13th; Coopersburg, 14th; Greenville, 13th; Logania, 13th; Shingle House, 13th, 31st; Wellsboro, 13th; York, 13th, 14th.

Snow.—Hollidaysburg, 14th; Le Roy, 14th; Towanda, 14th; Cassandria, 14th; Johnstown, 14th; Emporium, 14th; Grampian, 14th; Saegerstown, 14th, 15th; Smethport, 14th; Blooming Grove, 14th; Shingle House, 14th; Dyberry, 14th.

Frost.—Pittsburg, 7th, 9th, 12th, 15th; Hollidaysburg, 7th, 12th, 15th, 16th, 18th, 19th; Le Roy, 14th, 15th; Towanda, 2d, 7th, 15th, 16th, 18th, 19th; Quakertown, 7th, 12th, 16th, 19th; Cassandria, 2d, 6th, 7th, 8th, 12th, 15th, 18th, 19th, 28th; Johnstown, 7th, 11th, 15th, 16th, 18th, 19th; Emporium, 12th, 18th, 19th, 29th; Mauch Chunk, 12th, 19th; State College, 6th, 12th, 15th, 19th; West Chester, 12th, 15th; Coatesville, 7th, 12th, 14th, 15th, 16th, 19th; Kennett Square, 7th, 12th, 15th, 16th; Westtown, 12th, 15th, 16th, 19th; Grampian, 7th, 19th; Lock Haven, 1st, 2d, 6th, 7th, 8th, 9th, 10th, 12th, 13th, 14th, 15th, 16th, 17th, 18th, 19th; Saegerstown, 15th, 16th; Carlisle, 12th, 15th; Harrisburg, 2d, 7th, 12th, 15th, 16th, 18th, 19th, 28th; Edinboro, 7th, 18th; Uniontown, 7th, 9th, 11th, 18th, 19th, 26th; Huntingdon, 12th, 15th, 16th, 18th; Coopersburg, 7th, 19th, 28th; Wilkes-Barre, 29th; Greenville, 7th, 15th, 18th, 26th; Pottstown, 12th, 16th; Easton, 7th, 15th, 16th; *Philadelphia* [Weather Bureau], 12th, 15th, 16th; [Centennial Avenue], 12th, 15th; Shingle House, 18th; Selins Grove, 2d, 6th, 7th, 8th, 9th, 10th, 14th; Somerset, 6th, 11th, 14th, 15th, 16th, 17th, 18th, 24th, 26th; Wellsboro, 2d, 7th, 12th, 14th, 15th, 29th; Dyberry, 2d, 7th, 8th, 9th, 12th, 16th, 18th, 19th, 28th; Honesdale, 3d, 6th; Hamlinton, 15th, 18th, 19th, 28th; South Eaton, 7th, 12th, 15th, 16th, 19th, 28th; York, 2d, 7th, 12th, 19th, 28th; Lancaster, 6th, 7th, 12th, 15th, 28th; Lebanon, 12th, 15th, 16th, 18th; Phoenixville, 7th, 15th, 16th; Lewisburg, 11th, 12th, 14th.

Sleet.—Wellsboro, 13th.

Coronæ.—Saegerstown, 9th; Lebanon, 18th.

Solar Halo.—*Philadelphia* [Centennial Avenue], 19th.

Meteors.—Emporium, 28th.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin.																																
Bethlehem,			.61							2.11			.26										.88		.47					.71	5.04
Blooming Grove,				.87					.70	2.27			.46											1.48	.52						‡1.12	6.42
Browers Lock,				.72	.05					2.99			.26							.20				.49					.08		.81	5.60
Coatesville,			.05	.42						3.19			.42							.43				.16							.90	5.17
Coopersburg,				.57	.01					2.44			.59	.01						.75		.01		.41	.01					.03	.79	5.62
Doylestown,				.59	.19				1.85				.38							.27				.51							1.04	4.84
Dyberry,				.95	.11				.14	2.26			.36							.42				.11							1.08	5.43
Easton,					.75					2.48			.33	.02								.01			1.25				.01	.03	.79	5.47
Forks of Neshaminy,				.30	.13					1.96			.44							.12				.56					.12	.05	1.30	5.38
Frederick,				.26	.15					2.28			.38							.74				.41							.77	4.40
Hamburg,			.74							2.45			.53										1.89								.82	6.36
Honesdale,	.01			.98	.03	.02			.12	2.35			.41	.02	.02							.03		.42	.11						1.09	5.61
Kennett Square,				.45	.05					2.45			.45										.44	.44				.10	.09	.98	.10	5.48
Lansdale,				.19	.49						2.61		.41											.31	.33	.21					1.00	5.55
Mauch Chunk,				.36	.03					3.46			.62	.05										.39	.20						1.35	7.06
Ottsville,				.41	.06					1.61			.47									.01		1.00	.38	.03					.98	4.95
Philadelphia, 2†				.21	.01					1.76			.55											.23	.58			.01	.07	.03	1.21	4.86
Philadelphia, b,				.44	.01					2.33			.39											.34	.75				.13	.01	1.22	5.62
Phœnixville,			.63	.01	.06					3.41			.36	.03						.01				.70	.04				.10	.40	.43	6.17
Point Pleasant,			.16	.21							1.66		.50											.45	.69					.03	1.05	4.75
Pottstown,			.17	.12						2.55			.40											.75							.81	5.20
Quakertown,				.61	.06					2.41			.50												1.38						1.80	5.80
Reading,				.60	.02					3.57			.24	.02								.01		.80	.56				.01	.01	.36	6.40
(Salem Corners) Hamlinton,				.90	.06	.04			.03	2.00	.03		.34	.14	.02									.37	.23	.02					1.00	5.18
Seisholtzville,				.59						2.85			.39										2.30	.49						.86	7.48
Smith's Corner,				.38	.07					1.76			.56											.49	.88					.04	1.05	5.23
Swarthmore,			.32							2.23			.31												.65						1.23	4.74
West Chester,				.61	.22					2.48			.40											.62	.55				.13	.02	.94	5.19
Westtown,			.01	.40	.10					2.60			.35				•								.85				.13	.04	1.10	5.58
Susquehanna Basin.																																
Altoona,				.16					.07	.48			.18	.06										.12							.70	1.77
(Aqueduct) Logania,				.40	.03					2.15			.65	.02										.87	.05						1.39	5.56
Bloomsburg,																																
Carlisle,									2.35				1.01												.72					.31	4.58
Drifton,				.36	.10		•		.80	2.44			.34	•							•			.03				•		.12	.94	5.15
Emporium,				.27	.07	.05		.15		.47			.73			.07								1.35			.03				.75	3.94
Gettysburg,																																
Girardville,				1.18	.26				2.92				.80											.80	.15						1.55	7.66
Grampian,				.23	.04	.05			.08	.38			.75	.21										.48							.75	2.97
Harrisburg,†				.37	.46	.02				1.50			.25	.04										.92	.02						1.02	4.60
Hollidaysburg,		•		.26		.04		.05		.67			.35	.06										.19						.03	.71	2.36
Huntingdon,	.03			.40		.02				.85			.33	.06										.35	.01						.89	2.93
Kilmer,				1.05					.10				.75	.01										.86							2.13	6.30
Lancaster,				.80	.04					2.30			.15											.91	.21						.53	5.36
Lebanon,				.34	.36					2.85			.36											1.12	.10				.05		.94	6.24
Le Roy,	.04			.06	.08	.29			.22	1.80			.19			.03								1.24	.24	.01					1.09	5.89
Lewisburg,				.74	.14				.08	1.57			.37											1.71	•		•				1.41	6.02
Lock Haven,	.42			.20	.02	.01		.06		1.67			.48											1.66	.06						1.05	5.73
Selins Grove,				1.64	.41			.03	.03				.47											.78							1.25	5.38
South Eaton,				.84		.10			.34	2.10			.58											.98	.44						1.22	6.30
State College,				.27	.02				.09	1.04			.41			.01								.47	.02				.02		.79	3.14
Towanda,	.07			.51	.20				.28	2.16			.04			.03								1.72							.95	5.97
Wellsboro,				.20	.04		.05		.15	1.20			.20	.10										.02	.30						1.55	3.81
Wilkes-Barre,										4.02			.47											.43							.61	5.53
York,				.33						2.01			.24									.01		.80	.02				.09		.81	4.24

†U. S. Weather Bureau Stations. • Missing. ‡Total rainfall for 30th and 31st. ‖ Total rainfall from 22d to 25th, inclusive. ‡Total rainfall from 29th to 31st, inclusive.

DURING OCTOBER, 1894.

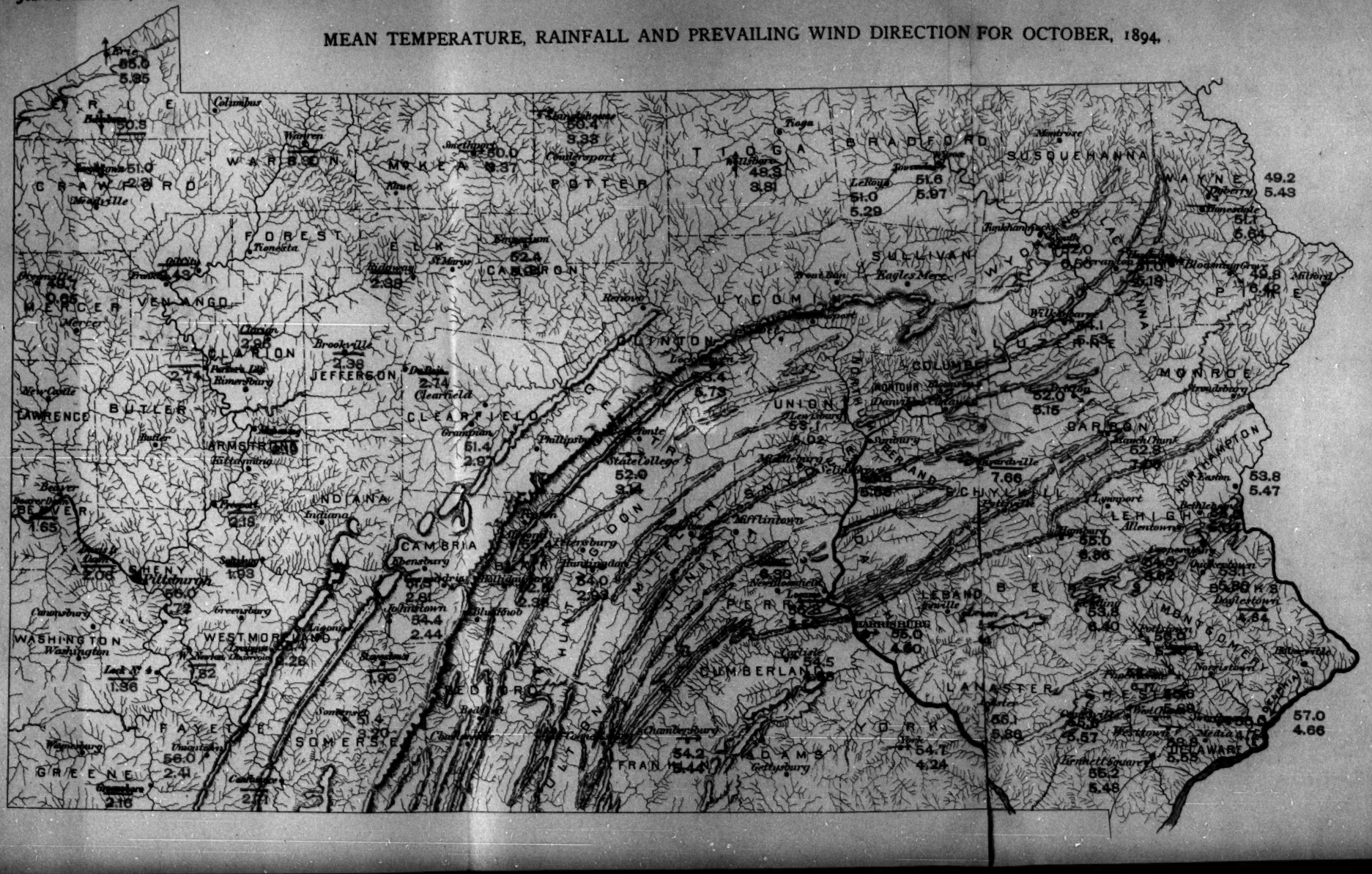
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		Total.
Ohio Basin.																																
Beaver Dam,											.03		.19	.20		.05							.28	.25							.75	1.65
Brookville,				.11	.27	.14							.20	.16	.07									.72							.41	2.38
Cassandria,				.33	.04	.03			.14		.59			.34	.30									.22							.87	2.81
Clarion,				.08	.05	.13	.03				.09		.22	.20	.35								.17	.65							.58	2.95
Confluence,	.28			.11		.12			.01	.55	.04		.25	.20	.03									.13							.69	2.71
Davis Island Dam,				.04		.12					.01		.14	.13		.06							.32	.30							1.09	2.06
DuBois,				.20	.07	.10			.02	.14	.18		.28		.11	.01								.81	.05						.77	2.74
Elwood Junction,				.04		.07						.04	.22	.16	.11	.08							.24	.21							.82	1.99
Freeport,	.27			.10	.03	.08					.05		.19	.13		.09							.22	.20							.82	2.18
Greensboro,				.30		.05				.25			.30	.25									.17	.01							.63	2.16
Greenville,						.22						.08	.28											.03						.04		0.65
(Immel Reservoir) Lycippus,			.40					.02	.47	.05	.40		.28										.15	.25							.80	2.28
Johnstown,	.01		.33	.05	.06							.34	.10	.05		.01								.28						.66	.01	2.44
Kane,																																
Ligonier,																																
Lock No. 4,	.08			.12		.07				.03			.17			.05							.05	.25							.54	1.36
Mahoning,				.07	.05	.05							.29	.47	.36	.08							.14	.14							.86	2.19
Oil City,				.05	.04	.10			.01		.08		.14	.14	.36	.08							.14	.36							.85	2.43
Parker's Landing,	.13			.11	.12	.21					.05		.35	.20	.17	.03							.13	.30	.01						.93	2.74
Pittsburg,†			.03		.05								.22	.03		.02						.44	.02	.25					.05		.02	1.72
Ridgway,	.11			.16	.09	.18			.12	.06			.24	.04	.04								.09	.36							.71	2.38
Saegerstown,				.06	.12	.40		.04		.03	.30		.25	.15	.20	.16								.19							.70	2.31
Saltsburg,	.02			.26	.06	.07				.11			.20	.25		.05								.19							.82	1.93
Shingle House,			.14	.08	.05	.17		.15		.33	.14		.30	.02		.07							.10	1.31							.47	3.33
Smethport,			.12		.30	.20				.20						.10							.05	1.20							.65	3.37
Somerset,			.15						.35			.35											.80							.35		3.20
Stoyestown,			.36				.29		.28	.13	.03		.06	.26	.22									.38								1.90
Uniontown,			.47		.08					.38			.37										.14							.48	.49	2.41
Warren,					.15	.26			.06		.45	.08	.31	.20	.01	.05								1.15	.03							.71	3.30
West Newton,			.17	.02	.06					.07	.03		.30	.15		.03							.02	.33							.04	1.88
Potomac Basin.																																
Chambersburg,			.62	.03	.08					1.58			.33										.02	1.40							1.44	5.44
Lake Basin.																																
Erie,†			.24	.19	2.15	.35		.04		.02	.14	.04	.26	.30								.16		.03	.62					.03	.78	5.35

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for October, 1894.

County.	Station	Elevation above Sea Level (feet).	Temperature. Mean.	Maximum. Highest.	Maximum. Date.	Minimum. Lowest.	Minimum. Date.	Mean of Maximum.	Mean of Minimum.	Daily Range. Mean.	Daily Range. Greatest.	Precipitation. Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rain or Snow.	Number of Days. Clear.	Fair.	Cloudy.	Wind. Prevailing Direction.	Observers
Allegheny,	Pittsburgh,	820	56·0	82	19	34	15	66·2	46·5	19·7	38	1·72	. .	. .	10	10	15	6	NW	O. D. Stewart, W. B.
Berks,	Hamburg,	380	55·0	77	2	31	16	64·4	45·7	18·7	36	6·36	. .	. .	5	9	12	10	W	William Shipe.
Berks,	Reading,[2]	280	53·8	. .	. .	. .	. .	. .	. .	. .	. .	6·40	. .	. .	11	. .	. .	. .	. .	Franklin Yager.
Berks,	Reading,[2]	280	53·8	. .	. .	. .	. .	. .	. .	. .	. .	1·77	. .	. .	7	. .	. .	. .	. .	Dr. C. B. Dudley.
Blair,	Altoona,	1,181	57·4	79	1	37	15	65·4	49·4	16·0	27	2·36	T	. .	9	15	1	14	W	Prof. J. A. Stewart.
Blair,	Hollidaysburg (30 days),	947	52·5	82	20	26	12	65·8	39·2	26·6	49	2·36	T	. .	9	15	2	14	SW	G. W. T. Warburton.
Blair,	Le Roy,	1,400	51·0	74	20	29	15	59·2	43·0	16·1	35	5·29	T	. .	12	13	2	16	SW	Hiram E. Bull.
Bradford,	Towanda,		51·6	76	3, 21	29	16	61·4	41·9	19·5	35	5·97	T	. .	9	12	4	15	W	
Bradford,	Towanda,											5·38	. .	. .	9	11	11	9	NW	J. C. Hileman.
Bucks,	Forks of Neshaminy[1],	304	56·3	. .	. .	. .	. .	. .	. .	. .	. .	3·80	. .	. .	6	9	13	9	SW	J. L. Heacock.
Bucks,	Quakertown,	536	53·1	78	3	29	16	63·3	42·9	20·4	38	2·81	3·0	. .	9	6	13	12	NW	A. H. Boyle.
Cambria,	Cassandria,	2,100	51·3	73	3	31	15	58·6	44·0	14·6	35	2·44	T	. .	14	10	11	10	S	E. C. Lovetts.
Cambria,	Johnstown,	1,184	54·4	82	19	29	15	65·5	43·4	22·1	48	3·94	T	. .	10	10	8	13	E	T. B. Lloyd.
Cameron,	Emporium,	1,050	52·4	79	3	29	18	63·1	41·6	21·5	47	3·94	T	. .	8	15	5	11	W	F. C. Wintermute.
Carbon,	E. Mauch Chunk,	550	52·3	75	2	30	12, 16	69·2	42·4	19·8	38	7·06	. .	. .	. .	. .	. .	. .	. .	
Centre,	State College—Agricultural Experiment Sta.,	1,191	52·0	77	20	32	15	61·1	43·0	18·1	33	3·14	. .	. .	10	8	10	13	W	Prof. Wm. Frear.
Chester,	West Chester,	455	55·6	79	3	33	15	63·6	47·4	16·2	26	5·89	. .	. .	9	18	1	12	W	J. C. Green, D.D.S.
Chester,	Coatesville,	380	55·5	83	3	29	16	66·2	44·8	21·4	38	5·57	. .	. .	7	16	7	8	S	W. T. Gordon.
Chester,	Kennett Square,	375	55·2	81	3	31	16	65·0	45·3	19·7	35	5·48	. .	. .	10	15	1	15	SW	B. P. Kirk.
Chester	Phœnixville,	190	55·5	79	3	33	16	64·3	46·7	17·6	34	6·17	. .	. .	12	11	5	15	NW	Knowles Croskey.
Chester,	Westtown (30 days),	350	53·8	80	3	32	16	61·3	45·8	16·1	30	5·58	. .	. .	9	11	8	11	W	John D. Carter.
Clearfield,	Grampian,	1,450	51·4	76	20	30	15	60·4	42·5	17·9	42	9·97	1·0	. .	9	8	12	11	SW	Nathan Moore.
Clinton,	Lock Haven,[1]	560	53·4	88	1	. .	. .	. .	. .	. .	. .	5·73	. .	. .	10	9	3	19	W	Prof. J. A. Robb.
Columbia,	Bloomsburg—State Normal School,	500	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	Prof. J. G. Cope.
Crawford,	Saegerstown,	1,200	51·0	80	21	25	18	63·6	38·4	25·2	48	2·31	T	. .	11	9	6	16	SE	J. G. Apple.
Cumberland,	Carlisle (29 days),	480	54·5	83	3	31	16	65·6	43·4	22·2	40	4·58	. .	. .	4	14	8	7	W	J. E. Pague.
Dauphin,	Harrisburg,	480	55·0	81	3	36	16	63·0	48·0	15·0	29	4·60	. .	. .	9	10	11	10	W	F. Ridgway, W. B.
Delaware,	Swarthmore—Swarthmore College,	361	56·0	80	3	34	16	63·2	48·9	14·3	30	4·74	T	. .	6	10	14	7	W	Prof. S. J. Cunningham.
Erie,	Edinboro,[2]	190	50·8	73	21	28	16	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	S	C. F. Sweet.
Erie,	Erie,	1,400	55·0	81	21	35	14	63·0	47·0	16·0	31	5·35	. .	. .	15	6	14	11	S	P. Wood, W. B.
Fayette,	Uniontown,	681	56·0	80	2	30	15	66·9	45·2	21·7	38	2·41	. .	. .	7	17	7	7	SW	Wm. Hunt.
Franklin,	Chambersburg,	1,000	54·2	84	3	30	16	65·5	42·8	22·7	39	5·44	. .	. .	8	12	10	9	W	J. C. Boggs.
Huntingdon,	Huntingdon—The Normal College,	650	54·0	81	3, 20	27	18	66·8	41·2	25·6	44	2·93	. .	. .	9	16	5	10	W	Prof. W. J. Swigart.
Lancaster,	Lancaster—Franklin and Marshall Col'ge,	413	55·1	82	3	30	16	65·4	44·8	20·6	34	5·36	. .	. .	7	13	12	6	SW	A. V. Helster.
Lebanon,	Lebanon,	458	54·4	81	3	30	16	64·7	44·0	20·7	36	6·24	. .	. .	9	15	6	10	NE	G. W. Hayes, C. E.
Lehigh,	Coopersburg,	400	54·3	76	3	35	15	60·4	43·6	16·8	32	5·62	. .	. .	11	14	10	7	SE	Dr. M. H. Boye.
Luzerne,	Drifton (27 days),	1,683	52·0	77	2	35	15	60·4	43·6	16·8	32	5·15	. .	. .	8	11	5	11	NW	J. R. Wagner.
Luzerne,	Wilkes-Barre,	575	51·1	80	1, 19	31	15, 20	65·0	43·2	21·8	42	5·53	. .	. .	4	8	13	10	W	A. W. Betterly.
Luzerne,	Kane,	2,000	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	C. H. Kemp.
McKean,	Smethport,	1,500	50·0	78	19, 20, 21	26	18	60·8	39·1	21·7	51	3·37	T	. .	9	9	8	14	W	Armstrong & Brownell.
McKean,	Greenville—Thiel College,	1,000	49·7	81	21	28	15	61·0	38·4	22·6	42	0·65	. .	. .	5	14	4	13	. . .	Prof. S. H. Miller.
Mercer,	Pottstown,	150	56·0	80	3	33	16	65·3	46·8	18·5	36	5·20	. .	. .	6	13	10	8	NW	Charles Moore, D.D.S.
Montgomery,	South Bethlehem,		55·6	78	3	37	16	69·0	49·2	19·8	27	. .	. .	. .	. .	. .	. .	. .	. .	T. Merriman.
Northampton,	Easton—Lafayette College,	325	53·8	72	3, 4	35	15, 16	61·6	46·0	15·6	28	5·47	. .	. .	9	16	3	12	. . .	J. W. Moore.
Perry,	(Aqueduct) Logania,	367	51·3	79	3	32	12, 16	65·2	45·4	19·8	36	5·56	. .	. .	8	13	6	12	NW	Richard Callin.
Philadelphia,	U. S. Weather Bureau,	117	57·0	82	3	37	15	65·6	49·6	16·0	27	4·76	. .	. .	10	11	8	12	NE	L. M. Dey, W. B.
Philadelphia,	1529 Centennial Avenue,	120	57·6	81	3	37	15	. .	. .	. .	. .	5·62	T	. .	9	12	10	9	NE	John Comly.
Pike,	Blooming Grove,[2]	. .	49·8	78	20	31	28	. .	. .	. .	. .	6·42	T	. .	11	4	16	11	NW	John Grathwohl.
Potter,	Shingle House,	1,475	50·4	80	19, 21	24	18, 19	62·4	38·4	24·0	56	3·33	T	. .	13	12	5	14	W	C. D. Voorhees, M.D.
Snyder,	Selins Grove,	455	53·8	80	5	26	9	69·2	38·3	30·9	44	5·58	. .	. .	7	10	4	8	SW	J. M. Boyer,
Somerset,	Somerset,	2,250	51·4	84	2	26	15	65·5	37·2	28·3	43	3·20	. .	. .	5	8	17	6	SE	W. M. Schrock.
Tioga,	Wellsboro,[2]	1,327	48·3	78	20	24	15, 19, 20	65·2	41·0	24·2	42	3·80	. .	. .	10	9	5	17	S	H. D. Deming.
Union,	Lewisburg (29 days),	450	53·1	75	2	32	16	60·1	38·2	21·9	44	6·02	. .	. .	7	8	5	17	S	Prof. W. G. Owen.
Wayne,	Dyberry,	1,100	49·2	79	20	25	16	59·8	42·4	17·4	37	5·43	T	. .	8	14	4	13	NW	Theodore Day.
Wayne,	Honesdale,	1,000	51·1	73	2	31	16	59·8	42·4	17·4	37	5·64	. .	. .	13	15	5	11	W	Andrew Thompson.
Wayne,	(Salem Corners) Hamlinton,	1,600	51·0	80	20	30	15	59·4	42·7	16·7	36	5·18	. .	. .	13	9	8	14	W	T.B. Orchard, M.D.
Wayne,	(Immel Reservoir) Lycippus,	1,400	55·4	78	1, 22	29	15	63·8	46·9	16·9	31	2·18	. .	. .	6	. .	. .	. .	. .	Murray Forbes
Westmoreland,	Ligonier,	1,750	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	C. D. Ambrose.
Westmoreland,	South Eaton,	660	52·0	76	21	31	16	61·4	42·5	18·9	38	6·50	. .	. .	8	13	8	10	NW	B. M. Hail.
Wyoming,	York,	385	54·7	83	3	30	16	65·0	44·4	20·6	38	4·24	T	. .	8	13	13	5	W	Mrs. L. H. Grenewald.
York,																				

Mean temperature from maximum and minimum readings. * Extremes from dry thermometers. [1] Mean temperatures, 7 + 2 + 9 + 9 + 4. [2] Mean temperature 8 + 8 + 2.

MEAN TEMPERATURE, RAINFALL AND PREVAILING WIND DIRECTION FOR OCTOBER, 1894.


Erie 55.0 5.35
Columbus
Warren 50.9
Bradford 50.0
Coudersport 50.4 3.38
Tioga
Montrose
Wellsboro 48.3 3.81
Towanda
Wayne 49.2 5.43
Honesdale 51.1 6.64
Milford
Pike
Monroe
Stroudsburg
Northampton
Easton 53.8 5.47
Bethlehem
Lehigh
Allentown
Berks
Reading
Lebanon
Harrisburg 55.0 4.80
Lancaster
York
Adams
Gettysburg
Cumberland
Franklin
Chambersburg 54.2 5.44
Bedford
Somerset
Fayette
Uniontown 56.0 2.41
Greene
Washington
Westmoreland
Greensburg
Pittsburgh 56.0 2.08
Allegheny
Beaver 1.65
Lawrence
New Castle
Butler
Armstrong
Indiana
Cambria
Johnstown 54.4 2.44
Blair
Altoona 54.0 2.99
Huntingdon
Mifflin
Juniata
Perry
Clearfield
Grampian 51.4 2.97
Jefferson
Brookville 2.38
Clarion
Venango
Mercer
Crawford
Meadville 49.1 0.65
Forest
Elk
McKean
Warren
Potter
Tioga
Bradford
Susquehana
Wyoming
Sullivan
Eagles Mere
Lycoming
Williamsport 54.1
Clinton
Centre
State College 52.9 3.14
Union
Snyder
Northumberland
Columbia
Montour
Luzerne
Wilkesbarre 48.8
Carbon
Schuylkill
Berks
Lehigh
Monroe
Pike
Milford
Delaware
Chester 57.0 4.66
Lancaster 56.1 5.38
Lebanon 55.0 4.80
Dauphin
Cumberland
Perry
Juniata
Mifflin
Centre
Clinton
Lycoming
Sullivan
Wyoming
Susquehanna
Bradford
Tioga
Potter
McKean
Elk
Cameron
Forest
Warren
Crawford
Erie
Mercer
Venango
Clarion
Jefferson
Clearfield
Cambria
Somerset
Bedford
Fulton
Franklin
Adams
York
Lancaster
Chester
Delaware
Montgomery
Bucks
Philadelphia
Lehigh
Northampton
Wayne
Pike
Monroe
Carbon
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Northumberland
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Luzerne
Lackawanna
Susquehanna
Wyoming
Sullivan
Tioga
Bradford

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189